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This study documents the existing impacts of storm water runoff loadings on Town Lake and Lake Austin water quality. It also characterizes runoff water quality from two low-to-medium density residential land uses, and one structural control measure. The storm water monitoring program was divided into a receiving water and a stormwater sampling program, and a detailed analysis of the survey data of each program is presented.

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and

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NATIONWIDE URBAN RUNOFF PROGRAM
IN AUSTIN, TEXAS

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THE CITY OF AUSTIN

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This report represents the culmination of two and one-half years of effort by the City of Austin, the Texas Department of Water Resources (TDWR), and the Environmental Protection Agency (EPA) to identify and characterize the impact of urban runoff from selected residential land uses in Austin, Texas. The study was jointly funded by the Nationwide Urban Runoff Program (75 percent) and the City of Austin (25 percent). Engineering-Science (ES) of Austin, Texas, was selected by the City of Austin as its contractor, with responsiblity for developing and implementing all field monitoring and data collection efforts, analysis of these data, and preparation of the necessary reports. City of Austin and TDWR staff were responsible for administering the program. City of Austin staff were responsible for construction of runoff gauging stations, assistance to ES staff during runoff event monitoring, and all aspects of the public participation program. In addition, City staff members actively participated in various tasks and in the preparation of this final report through their review efforts.

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ABSTRACT

This report presents an overview of the Nationwide Urban Runoff Program in Austin, Texas. The study documents the existing impacts of storm water runoff loadings upon Lake Austin and Town Lake water quality (two lakes within the Austin metropolitan area), and characterizes runoff water quality from two low-to-medium-density residential land uses and one structural control measure. The storm water monitoring program was divided into a receiving water and a storm water sampling study. The storm water sampling study involved an examination of two test watersheds and analyzed the mitigating effects of percent of impervious cover and storm water retention on runoff pollutant loads. The two test watersheds were evaluated on the basis of such storm water quality parameters as chemical oxygen demand, biochemical oxygen demand, total organic carbon, ammonia, phosphates, suspended solids, fecal coliforms, metals, and toxic organics. The receiving water study emphasized water quality sampling, sediment quality sampling, and the analysis of resident fishes for selected indicators of urban storm water pollution (i.e., metals and pesticides). A detailed analysis of both the storm water runoff monitoring data base and the receiving water survey data are presented.

Data developed for Austin residential land use indicated that a medium-density residential land use (impervious cover approximately 39 percent) does produce a larger runoff pollutant load than a low-density residential land use (impervious cover approximately 21 percent) primarily because of the quantity of storm water runoff from the two areas. Other than the presence of measurable quantities of lead and zinc, only trace levels of insecticides and defoliants were present in the storm water runoff samples collected from the two test watersheds. Comparison of runoff and pollutant loadings from the two residential areas with those from an undeveloped area with otherwise similar hydrologic characteristics clearly indicated that urbanization of lands with this type of geology, soils, vegetation, and topography significantly increases runoff pollutant loads.

Storm event oriented water quality sampling on Town Lake and Lake Austin indicated that the short-term effects of runoff-generated pollutants on receiving water quality can be significant, although chronic water quality impacts were not apparent. Lake bottom sediments contained environmentally

persistent constituents (i.e., metals and pesticides) which probably were deposited over many years. The concentrations of metals and chlorinated hydrocarbon pesticides and PCBs measured in the tissues of fish samples collected from both Town Lake and Lake Austin were not at a level considered hazardous to public health.

The total chemical cost associated with the treatment of drinking water was affected by storm water runoff and subsequent lake water quality. The incremental increase in cost of treatment is minimal, however, based on the magnitude of the difference and the small percentage of time during the year that the situation occurs.

INTRODUCTION

Recognizing that a unique opportunity exists in the Austin area to document the impact of urbanization on a relatively undisturbed receiving water body, a study was initiated in accordance with the Nationwide Urban Runoff Program (NURP) of the U.S. Environmental Protection Agency (EPA) to develop a comprehensive technical document for continuing water quality management in the Lake Austin watershed. The specific objectives of this urban runoff study were:

1. To document the existing impacts of storm loadings on Lake Austin and Town Lake water quality and aquatic ecology.
2. To quantify the storm water runoff pollutant loads from selected land use categories, with respect to the degree of urbanization (percent of impervious cover), and to examine a representative structural control measure in one of the test watersheds.

In order to determine the runoff quality and its impacts on the lake water, the field survey involves two aspects, namely, storm water monitoring and receiving water sampling. The Lake Austin NURP study had as its basis the implementation of a storm water sampling program designed to investigate the effectiveness of runoff control measures (both structural and nonstructural) in insuring appropriate water quality protection at a reasonable cost and which would produce the greatest benefit.

The several drainage areas which were monitored during the course of the Lake Austin study were selected based upon distinct differences in percent of impervious cover or upon the availability of structural control devices. The program had as its focus the evaluation of the effectiveness of two preventative measures for storm water control that could be applied to new developments within the Lake Austin watershed, thereby protecting the lake from possible degradation and future impairment of its beneficial uses.

The receiving water survey, on the other hand, was conducted as a supporting part of the storm water study. The receiving water study was designed to determine if water quality degradation could be detected during a nonpoint source event, and whether the apparent deterioration could be attributed directly to urban runoff.

BACKGROUND ON THE PROJECT

PURPOSE OF THE PROJECT

Storm Water Monitoring Studies

The objective of this portion of the Austin NURP study was to evaluate the effectiveness of storm water control measures that could be applied to new development to protect the waters of Lake Austin from degradation and the eventual impairment of its beneficial uses. Due to the relatively undeveloped nature of the Lake Austin watershed, the results of the study should be directly applicable to the creation of planning tools which could be implemented in order to evaluate future development within the drainage basin. The study focuses on the Lake Austin watershed, although drainage areas located outside of the immediate basin but having similar topographic and geological characteristics were monitored to accomplish the study objectives.

In an effort to mitigate the possible deterioration of Lake Austin, the City of Austin has instituted a policy of implementing structural and nonstructural storm water runoff control measures for the Lake Austin watershed. This study investigates storm water runoff quality as it is related to selected structural and nonstructural nonpoint source control measures. The specific nonstructural control measure selected for study uses the concept of impervious cover as a measure of development intensity. This control measure is based on the supposition that a reduction in the extent of impervious surface will correspond to a decrease in storm water runoff and a subsequent reduction in pollutant loadings. The specific structural control measure that was examined within the context of this study involves the detention of storm water. This control device should facilitate the deposition of a significant portion of the accompanying pollutant load while attenuating peak flows downstream. The storm water sampling program was implemented to investigate the efficacy of both the structural and nonstructural nonpoint source control measures, and to provide data for evaluating their effectiveness in preserving Lake Austin and other similarly valuable water resource sites within the Austin urban area.

Receiving Water Study

Another aspect of the Urban Runoff Program in Austin addressed differences in water quality parameters and biological indicators of water quality in both Lake Austin and Town Lake. The principal objective of this portion of the study was to document the current impacts of urbanization and urban-related runoff pollutant loads upon these receiving water bodies. This aspect of the study provided the opportunity to assess the effects of storm water pollution from both limited residential development and undeveloped areas on the water quality in Lake Austin proper.

The rationale behind the NURP receiving water study emphasized the following premises:

1. The available ongoing water quality sampling programs in Lake Austin and Town Lake continually provide baseline information on the degree of water quality deterioration associated with the conventional pollutants in storm water runoff.

2. The most appropriate time to conduct water quality sampling in the receiving waters was during the period when the impact of hypolimnetic releases from Lake Travis is minimal and lake retention times are longest.

3. The information obtained from the storm water sampling program could be used to define the water quality parameters of concern in the receiving water monitoring study, especially when event-oriented sampling is undertaken.

4. A preliminary screening study involving the collection of numerous sediment grab samples in Town Lake and Lake Austin could be used to develop a profile of ambient levels of toxic materials deposited in the receiving waters. (Toxic materials identified during actual storm water runoff sampling and found in the sediment sample analysis for the receiving waters were investigated thoroughly during the receiving water study).

5. The sampling of biological indicators could be oriented to potential problem areas where toxic organics (i.e., pesticides) and other water quality parameters might present a harmful ecological impact. (Pre-event and post-event biological monitoring would only be warranted at sites experiencing changes in the aquatic biota during nonpoint source events.)

DESCRIPTION OF THE STUDY AREA

Lake Austin is one of seven central Texas reservoirs called the Highland Lakes that were built within a 150-mile reach of the Colorado River. The lower three reservoirs, Town Lake, Lake Austin, and Lake Travis, are within Travis County, Texas, while both Town Lake and Lake Austin are in the vicinity of the Austin metropolitan area. The three impoundments, Lake Travis, Lake Austin, and Town Lake, are subject to varying degrees of urban development and urban-related runoff loadings in their respective watersheds. An increasing urban density is encountered downstream from Lake Travis toward Town Lake as is depicted in Figure 1.

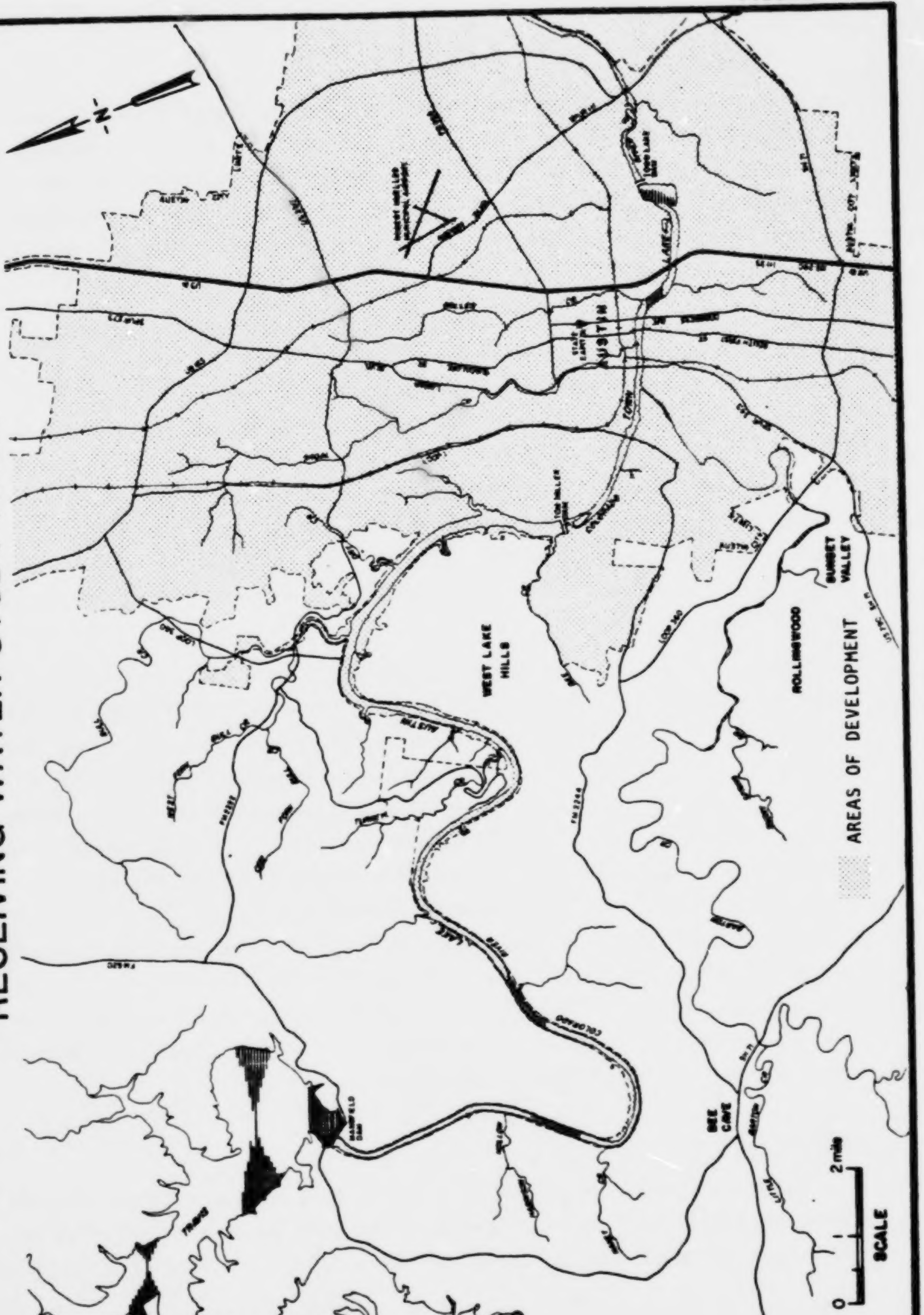
Much of the Lake Travis watershed is undeveloped and serves as a major recreation area. Limited low-density residential development does exist in several locations along the shoreline, and these areas include both vacation and permanent homes. In actuality, urban-related runoff loadings to Lake Travis are of minor concern since such areas constitute a relatively small portion of the watershed. The waters of the Lake Travis impoundment function as a control for documentation of storm water runoff impacts upon Lake Austin since releases from Lake Travis are made directly to Lake Austin at regular intervals during the spring and summer.

The Lake Austin impoundment is a typical riverine reservoir; namely, long, narrow, and shallow. During periods of scarce precipitation, the flow characteristics of the lake are dictated by the releases from Lake Travis. The upper portions of the Lake Austin watershed are sparsely developed, while generally low-density residential land use is encountered in the lower reaches of the impoundment. (This low-density residential development provides the focus of the study). Presently, the only significant urban-related runoff pollutant loads to Lake Austin enter in the lower portion of the reservoir.

Situated immediately downstream of Lake Austin is Town Lake (the younger of the two lakes), which is approximately five miles long and relatively narrow and shallow. The flow characteristics of Town Lake during dry weather are dictated by the releases from Lake Austin, although this flow is augmented by significant spring-fed inflows from Barton Creek. Barton Creek inflows are most significant during the fall and winter when Lake Austin discharges are at

FIGURE 1

RECEIVING WATER STUDY AREA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AUSTIN
TOWN LAKE
STATE CAPITOL
WEST LAKE HILLS
ROLLINGWOOD
SUNSET VALLEY
BEE CAVE
MANSFIELD DAM
LAKE AUSTIN
COLORADO
LOOP 360
FM 2244
LAKE TRAVIS
AREAS OF DEVELOPMENT
0
1
2 mile
SCALE

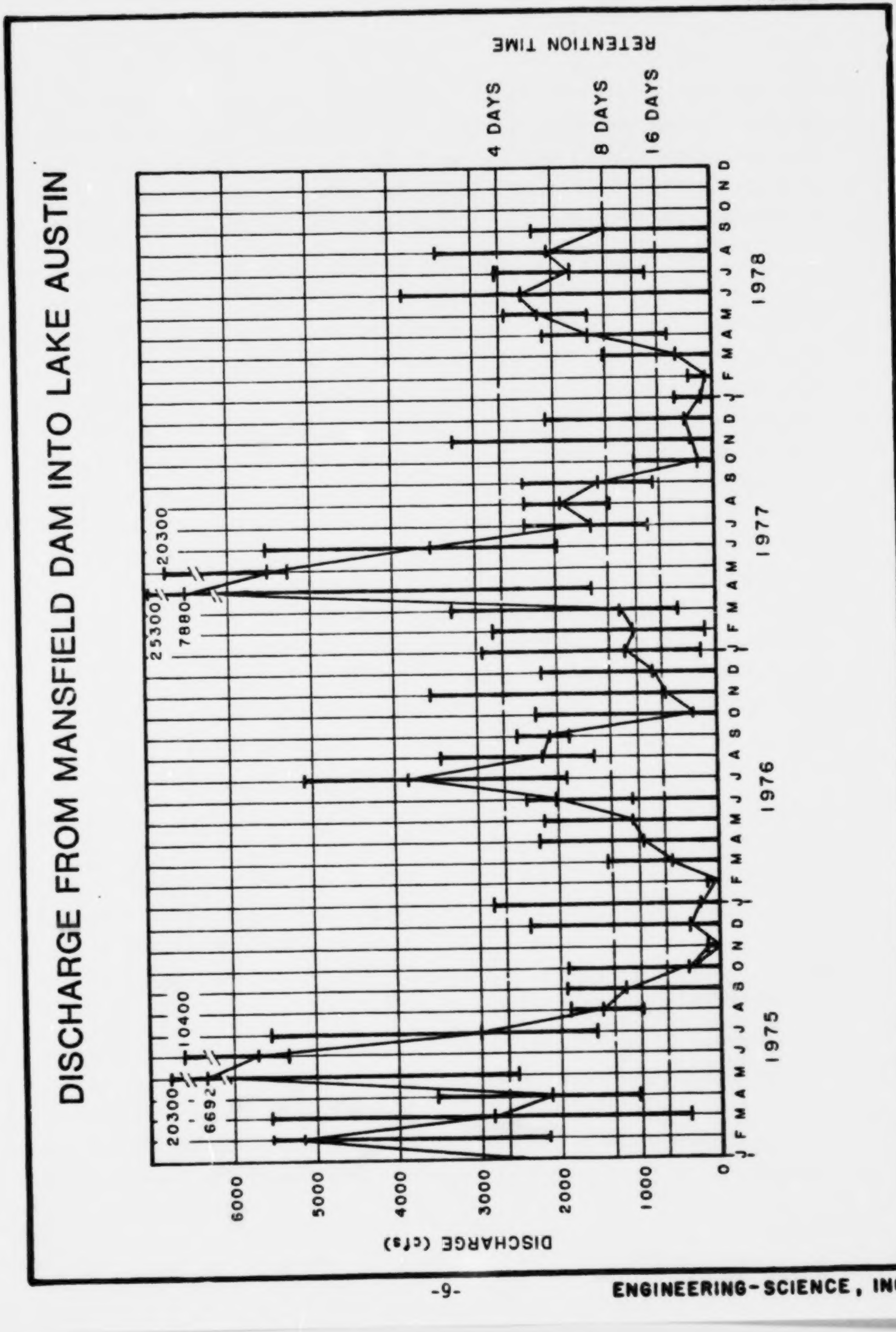
a minimum. The waters of the lake are used to a limited degree as a water supply during peak demand periods. Town Lake is the receiving body for substantial quantities of urban storm water runoff from primarily high-density residential and commercial areas in its lowermost reach. (These areas are not the subject of this investigation). Much of the City of Austin lies in the watershed of Town Lake.

A large percentage of the study area can be characterized as rugged hill country with slopes that generally range from two to 15 percent. Soil slopes greater than five percent are present along the eastern edge of the Edwards Plateau, while they average about five percent within the Balcones Escarpment. The Austin area extends from the hill country at the eastern edge of the Edwards Plateau across the Balcones Fault Escarpment, which represents the demarcation of the Edwards Plateau and the Grand Prairie. The Balcones fault zone is the most prominent geological feature in the study areas. This fault zone separates the Gulf Coastal Plain from the Edwards Plateau, marking the rim of the Gulf Basin.

The hydrological characteristics of Lake Austin and Town Lake (two riverine impoundments) are similar to river systems rather than acting as true limnological systems. The release of large amounts of water from the hypolimnion of Lake Travis into the Lake Austin-Town Lake system (during the spring and summer months) ensure that the ambient water quality in these lakes will be a function of the prevailing conditions in the hypolimnion of Lake Travis. This relationship is particularly apparent during the spring and summer months when downstream irrigation demands are greatest and large-scale releases of lake water are commonplace. During the winter when flood control considerations predominate, releases through Mansfield Dam are minimal (see Figure 2) and the ambient water quality conditions throughout the Lake Austin-Town Lake system, particularly for nonconservative constituents, are more variable due to the much longer lake retention times.

EXISTING DATA BASE

There are several sources of water quality data available for the Highland Lakes, including Lake Austin, from past and ongoing water quality survey programs. The United States Geological Survey (USGS) is presently collecting



DISCHARGE FROM MANSFIELD DAM INTO LAKE AUSTIN flow and water quality information in the Austin area which is supplementing the data obtained from the Lake Austin storm water runoff study. The principal data sources besides the USGS are the City of Austin and the Texas Department of Water Resources (TDWR). Data from these monitoring programs were utilized to develop a baseline water quality assessment for Lake Austin and Town Lake.

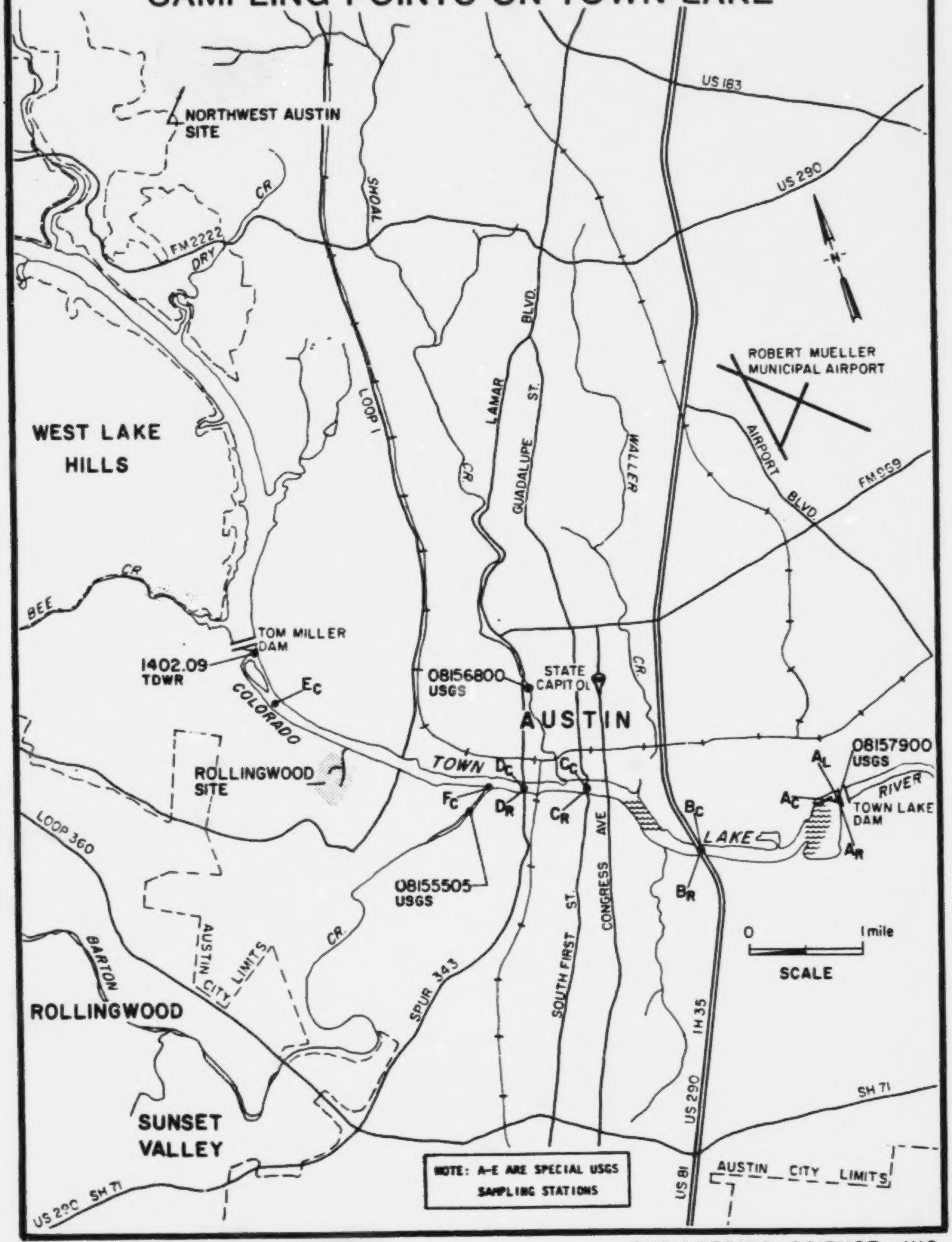
Since 1975, the USGS and the City of Austin have jointly maintained an urban runoff sampling program on Town Lake, Lake Austin, and most of their tributaries. The location of the various sampling stations established by the existing program on Town Lake and Lake Austin are presented in Figures 3 and 4, respectively. Since the inception of the USGS-City of Austin program, the number and location of sampling stations have increased to six on Town Lake and five on Lake Austin. Samples are collected at various points within the lake cross-section and at various depths to provide more detail regarding the spatial distribution of water quality constituents. These monitoring surveys are conducted periodically for a complete array of water quality constituents, including heavy metals, pesticides, and toxic organics. This cooperative program also includes monitoring of two storm events per year on various lake tributaries where storm water monitoring stations are established. Such storm water runoff sampling, however, usually is limited to runoff volume measurements from which a hydrograph is generated, although runoff quality parameters also may be measured at various points along the hydrograph.

The TDWR also maintains a limited sampling program which includes six stations along Town Lake (primarily at the confluence with major tributaries) and two stations on Lake Austin. The TDWR program monitors the typical conventional water quality parameters, such as dissolved oxygen, biochemical oxygen demand (BOD), chemical oxygen demand (COD), nutrients, chlorides, sulfates, and coliform bacteria. A listing of the various water quality parameters that are monitored by the various ongoing sampling programs in Lake Austin and Town Lake are presented in Tables 1 and 2.

Historical data which depict the annual average values for selected water quality parameters sampled from existing survey stations in Town Lake and Lake Austin are presented in Tables 3 and 4, respectively. In contrasting these background water quality data for the two lakes, observable differences are apparent for such parameters as turbidity, total alkalinity, hardness, and

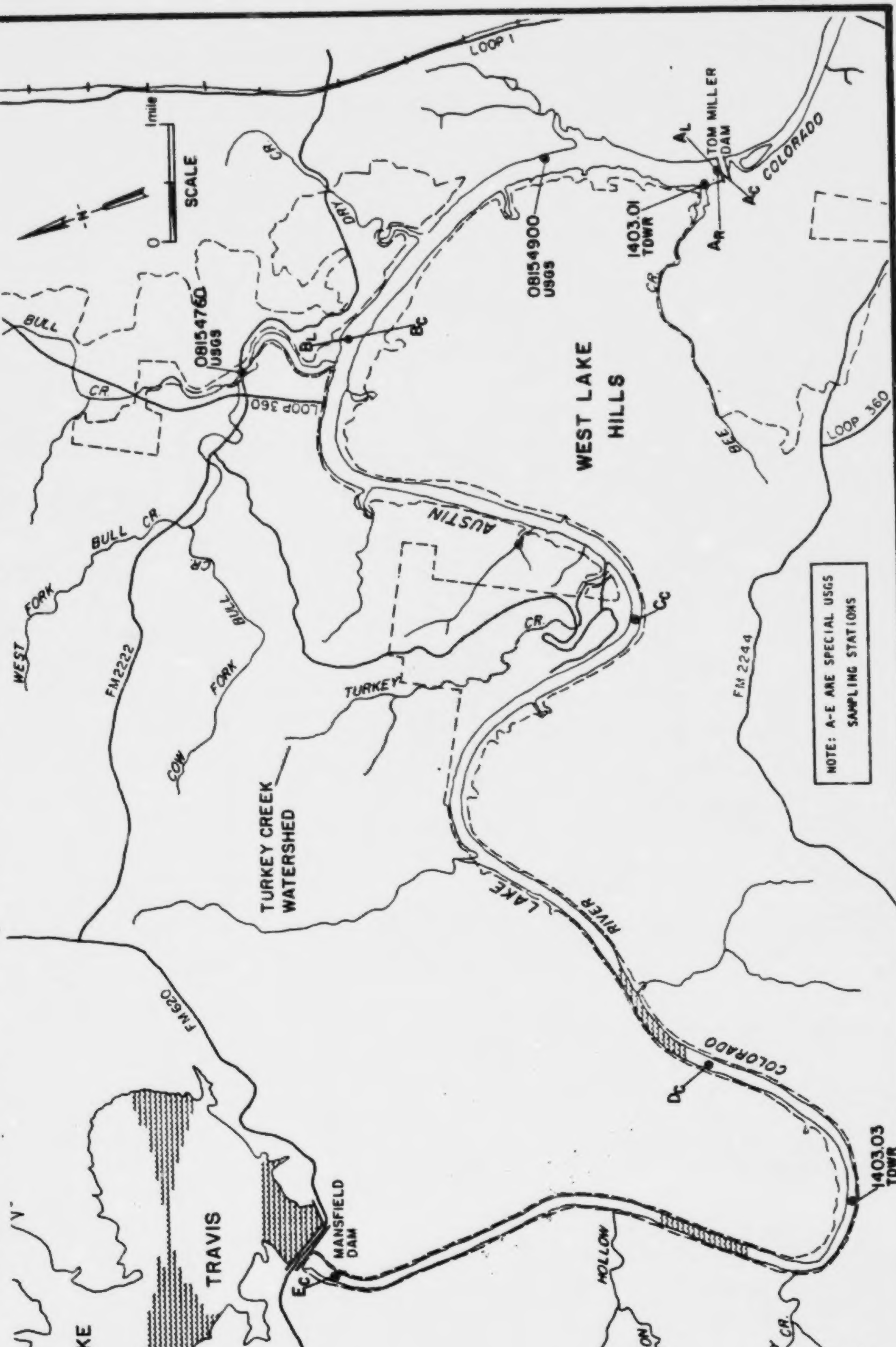
FIGURE 3

LOCATION OF EXISTING WATER QUALITY SAMPLING POINTS ON TOWN LAKE


NORTHWEST AUSTIN SITE
US 183
US 290
SHOAL
CR.
FM 2222
DRY
N
ROBERT MUELLER MUNICIPAL AIRPORT
LAMAR
BLVD.
ST.
LOOP 1
WEST LAKE HILLS
CR.
GUADALUPE
WALLER
AIRPORT
BLVD.
FM 969
BEE
CR
TOM MILLER DAM
1402.09 TDWR
COLORADO
E_C
08156800 USGS
STATE CAPITOL
AUSTIN
CR.
08157900 USGS
A_L
TOWN
D_C
C_C
RIVER
ROLLINGWOOD SITE
F_C
D_R
C_R
B_C
A_C
TOWN LAKE DAM
LAKE
A_R
LOOP 360
AVE
08155505 USGS
B_R
0
1 mile
SCALE
ST.
CONGRESS
SOUTH FIRST
CR.
BARTON
AUSTIN CITY LIMITS
SPUR 343
IH 35
ROLLINGWOOD
US 290
SH 71
SUNSET VALLEY
US 81
AUSTIN CITY LIMITS
US 290 SH 71

NOTE: A-E ARE SPECIAL USGS SAMPLING STATIONS

LOCATION OF EXISTING SAMPLING POINTS ON LAKE AUSTIN


SCALE
0
1mile
N
LOOP 1
TOM MILLER DAM
A_L
A_C
A_R
COLORADO
1403.01 TOWR
08154900 USGS
DRY CR.
BULL CR.
08154760 USGS
B_L
B_C
LOOP 360
WEST LAKE HILLS
BEE CR.
LOOP 360
AUSTIN
C_C
FM 2244
WEST FORK BULL CR.
FM2222
COW FORK BULL CR.
TURKEY CR.
TURKEY CREEK WATERSHED
LAKE
RIVER
COLORADO
D_C
1403.03 TOWR
FM620
LAKE
TRAVIS
MANSFIELD DAM
E_C
HOLLOW
HARRISON
HANEY CR.

NOTE: A-E ARE SPECIAL USGS SAMPLING STATIONS

TABLE 1

WATER QUALITY PARAMETERS
UTILIZED IN VARIOUS LAKE AUSTIN – TOWN LAKE SAMPLING PROGRAMS

Parameters	City of Austin Raw Water Intake Data	City of Austin Lake Sampling Program	USGS Lake Sampling Program	TDWR Lake Sampling Program
Temperature	✓	✓	✓	✓
Dissolved Oxygen		✓	✓	✓
Specific Conductance		✓	✓	✓
pH	✓	✓	✓	✓
Hardness	✓	✓		✓
Total Alkalinity	✓	✓		✓
Turbidity	✓			✓
Total Organic Carbon				✓
BOD_5		✓		✓
COD				✓
Total Solids			✓	
Total Suspended Solids			✓	✓
Total Dissolved Solids			✓	
Ammonia-N		✓	✓	✓
Nitrite-N			✓	
Nitrate-N		✓	✓	✓
Total Phosphate-N		✓	✓	✓
Chloride				✓
Sulfate				✓
Total Coliforms	✓	✓		✓
Fecal Coliforms	✓	✓	✓	✓
LAS		✓		
Oil and Grease		✓		

TABLE 2

ADDITIONAL WATER QUALITY PARAMETERS UTILIZED IN USGS LAKE SAMPLING PROGRAM

Arsenic
Barium
Cadmium
Chromium
Copper
Iron
Lead
Manganese
Mercury
Selenium
Silver
Zinc
PCB's
PCN's
Aldrin
Chlordane
DDD
DDE
DDT
Diazinon
Eldrin
Endrin
Ethion
Heptachlor
Heptachlor epoxide
Lindane
Malathion
Methyl parathion
Methyl trithion
Parathion
Toxaphene
Trithion
2,4-D
2,4,5-T
Silvex

TABLE 3

ANNUAL AVERAGE VALUES FOR WATER QUALITY PARAMETERS SAMPLED FROM TOWN LAKE STATIONS BY THE CITY OF AUSTIN

Location	Year	Temperature (°F)	Dissolved Oxygen (mg/l)	pH	Total Alkalinity (mg/l)*	Hardness (mg/l)*	BOD (mg/l)	Ammonia (mg/l)	Nitrate-nitrogen (mg/l)	Total Phosphate (mg/l)	Fecal Coliforms (No/100 ml)
Town Lake (Red Bud Isles)	1975	65.1	8.5	8.2	-	-	1.76	0.08	1.68	0.56	-
	1976	58.4	8.2	8.2	-	-	1.27	0.15	1.13	0.43	-
	1977	57.3	8.1	7.8	-	-	1.68	0.18	3.52	0.04	-
	1978	65.1	8.0	8.0	-	-	1.45	0.16	2.59	0.09	-
	1979**	65.5	8.6	7.7	218.1	253.5	0.84	0.21	3.59	0.03	123
Town Lake (Lamar Street Bridge)	1975	66.2	8.1	8.1	-	-	1.57	0.08	3.38	0.50	-
	1976	61.5	7.8	8.0	-	-	1.10	0.15	3.85	0.47	-
	1977	58.9	7.9	8.0	-	-	1.51	0.15	3.73	0.04	-
	1978	65.0	7.6	8.0	-	-	1.34	0.15	3.22	0.07	-
	1979**	63.5	8.2	7.7	254.5	282.4	0.95	0.23	3.83	0.03	396
Town Lake (Green WTP)	1975	64.0	-	8.0	170.6	209.9	-	-	-	-	76
	1976	63.2	-	8.0	183.6	225.3	-	-	-	-	75
	1977	63.3	-	7.9	166.9	212.0	-	-	-	-	87
	1978	63.8	-	8.0	169.3	218.6	-	-	-	-	446***
	1979	66.1	9.1	7.9	187.3	235.1	1.53	0.04	1.20	0.04	163
Town Lake (Congress Avenue Bridge)	1975	67.3	8.2	8.1	-	-	1.84	0.08	3.21	0.52	-
	1976	64.7	8.4	8.0	-	-	1.44	0.10	3.15	0.52	-
	1977	59.6	8.0	7.8	-	-	1.85	0.20	3.74	0.04	-
	1978	66.3	7.8	8.0	-	-	1.77	0.13	3.36	0.07	-
	1979	68.8	8.4	7.8	-	-	1.04	0.28	4.04	0.06	-
Town Lake (Longhorn) Dam)	1975	68.4	7.9	8.1	-	-	1.94	0.08	2.54	0.52	-
	1976	66.6	7.7	7.8	-	-	1.29	0.12	2.37	0.63	-
	1977	59.7	7.9	8.0	-	-	1.58	0.21	3.85	0.04	-
	1978	67.3	8.3	8.2	-	-	1.21	0.15	2.39	0.07	-
	1979	69.2	8.2	7.9	-	-	1.06	0.29	3.57	0.01	-

NOTE: Annual average values based on weekly average values.

*As $CaCO_3$.

**Average higher than normal due to data (8 values only) taken during October through December.

***Average higher than normal due to a few unusually high values.

TABLE 4

ANNUAL AVERAGE VALUES FOR WATER QUALITY PARAMETERS SAMPLED FROM LAKE AUSTIN STATIONS BY THE CITY OF AUSTIN

Location	Year	Temper-ature (°F)	Dissolved Oxygen (mg/l)	pH	Total Alkalinity (mg/l)*	Hardness (mg/l)*	BOD (mg/l)	Ammonia (mg/l)	Nitrate-nitrogen (mg/l)	Total Phosphate (mg/l)	Fecal Coliforms (No/100 ml)
Lake Travis (LCRA Park)	1975	68.1	9.1	8.4	-	-	2.0	0.06	1.23	0.47	-
	1976	63.5	9.0	8.4	-	-	1.4	0.14	0.56	0.41	-
	1977	62.0	8.4	8.4	-	-	1.8	0.14	2.60	0.04	-
	1978	65.5	9.0	8.4	-	-	1.4	0.10	2.24	0.06	-
	1979	69.9	8.6	8.3	153.6	190.9	1.2	0.21	2.38	0.03	1***
Lake Austin (Cooper's Landing)	1975	64.3	8.2	8.2	-	-	2.0	0.06	1.84	0.44	12
	1976	57.1	8.2	8.2	-	-	1.1	0.10	0.82	0.48	13
	1977	56.6	7.0	8.1	-	-	1.4	0.27	3.64	0.04	12
	1978	59.0	8.0	8.1	-	-	1.2	0.14	2.04	0.07	28†
	1979	59.9	7.9	7.9	160.3	195.0	0.9	0.22	2.64	0.02	55†
Lake Austin (City Park)	1975	-	8.9	8.2	-	-	1.5	0.10	0.89	0.49	4
	1976	67.0	10.1	8.2	-	-	1.4	0.07	1.08	0.36	8
	1977	67.4	8.5	8.1	-	-	1.7	0.20	3.32	0.04	10
	1978	61.0**	8.0	8.0	-	-	1.3	0.11	1.87	0.05	14
	1979	64.8	9.2	8.1	-	-	1.0	0.25	3.12	0.02	47†
Lake Austin (Davis WTP)	1975	65.9	-	8.3	156.9	201.2	-	-	-	-	16
	1976	67.4	-	8.2	158.7	201.3	-	-	-	-	12
	1977	65.7	-	8.2	151.7	202.6	-	-	-	-	7
	1978	66.7	-	8.2	149.8	203.8	-	-	-	-	12†
	1979	63.0	8.1	8.1	154.9	200.0	0.9	0.02	0.32	0.02	7
Lake Austin (Ullrich WTP)	1975	66.4	8.7	8.2	142.5	196.3	1.9	0.08	1.15	0.51	7
	1976	62.5	9.1	8.3	160.2	205.4	2.0	0.12	0.90	0.42	3
	1977	59.2	7.2	8.1	152.6	202.5	1.6	0.21	3.23	0.05	6
	1978	65.5	8.8	8.2	152.0	203.9	1.3	0.14	2.52	0.05	4
	1979	64.3	8.8	8.1	155.2	203.8	1.2	0.25	2.70	0.02	5

NOTE: Annual average values based on weekly average values.

*As $CaCO_3$.

**Average temperature lower than normal due to lack of late summer values.

***Average higher than normal due to data (8 values only) taken during October through December.

†Average higher than normal due to a few unusually high values.

fecal coliforms. The difference between the level of fecal coliforms in the waters of Town Lake and Lake Austin probably are attributable to the larger storm water runoff loadings in Town Lake; however, hardness and total alkalinity differences, especially during the winter months, are due to the influence of Barton Springs' flow contributions into Town Lake.

Lake Austin water quality, as monitored at the intake of the Davis Water Treatment Plant, however, does not appear to be impacted by the magnitude of water released from Mansfield Dam alone. The magnitudes of tributary stream flow rates and the nature of the basin bedrock also will influence the lake water quality. This relationship was examined by a multiple regression analysis procedure where the magnitudes of the dam discharges and stream flows were taken as independent variables and the alkalinity and hardness as measured in the raw influent waters to the water treatment plants were taken as dependent water quality variables. These data were obtained from the LCRA, USGS, and City of Austin. The correlation coefficients presented in Tables 5 and 6 show that there exists a relationship between the variables only during the period of minimum dam discharge (Condition 1) and the period of high dam and stream discharges (Condition 2).

A correlation between alkalinity and dam discharge appears to be evident during the low-flow period with a correlation coefficient of 0.634. However, during the high-flow period; the correlation coefficient for alkalinity drops significantly to 0.352. The correlation between hardness and dam discharge, on the contrary, shows a clear relationship with a correlation coefficient of 0.601 during the high-flow period; however, the correlation coefficient drops to 0.346 during the low-flow period. The transitional period of moderate dam discharges, as depicted in Tables 7 and 8, show no correlation between alkalinity and hardness with low stream flows (Condition 3). These moderate dam discharges also show no correlation with water alkalinity during periods of high stream flow (Condition 4), but a rather low correlation coefficient of 0.259 was calculated for water hardness.

The mean monthly total alkalinity, turbidity, and fecal coliform concentrations for raw influent waters to the three City of Austin water treatment plants are presented in Figures 5, 6, and 7, respectively. These data indicate

TABLE 5

WATER QUALITY PRIOR TO THE RAINY SEASON WITH MINIMUM DAM DISCHARGES AND LOW CREEK FLOWS

FEBRUARY 23 – MARCH 2, 1981

CONDITION 1

Discharge (cfs)			· Water Quality*** (mg/l)		
Date	Dam*	Bull Creek**	Date	Alkalinity	Hardness
February 23	157	4.2	March 3	145	185
24	683	4.1	4	142	184
25	38	4.1	5	142	182
26	0	4.1	6	144	192
27	0	4.1	7	144	195
28	0	4.1	8	144	192
March 1	0	6.3	9	144	184
2	0	5.3	10	146	188
			Correlation Coefficient	0.634	0.346

*Mansfield Dam (LCRA data).

**At Loop 360 (USGS data).

***At Davis Water Treatment Plant (City of Austin data).

TABLE 6

WATER QUALITY AFTER THE MEMORIAL FLOOD PERIOD WITH HIGH DAM DISCHARGES AND HIGH CREEK FLOWS
JUNE 2-11, 1981

CONDITION 2

Discharge (cfs)			Water Quality*** (mg/l)		
Date	Dam*	Bull Creek**	Date	Alkalinity	Hardness
June 2	2,117	19	June 12	150	190
3	2,117	80	13	150	195
4	4,644	55	14	150	196
5	5,529	42	15	169	210
6	5,529	33	16	169	218
7	5,405	27	17	163	202
8	5,529	23	18	159	205
9	5,323	26	19	160	203
10	4,317	760	20	160	205
11	5,529	168	21	152	202
			Correlation Coefficient	0.352	0.601

*Mansfield Dam (LCRA data).

**At Loop 360 (USGS data).

***At Davis Water Treatment Plant (City of Austin data).

TABLE 7

WATER QUALITY DURING THE DRY PERIOD WITH MODERATE DAM DISCHARGES AND LOW CREEK FLOWS
APRIL 16-25, 1981

CONDITION 3

Discharge (cfs)			Water Quality*** (mg/1)		
Date	Dam*	Bull Creek**	Date	Alkalinity	Hardness
April 16	1,728	3.0	April 26	144	196
17	1,859	4.3	27	146	192
18	1,951	5.0	28	146	192
19	1,725	4.5	29	146	193
20	2,631	4.0	30	146	193
21	2,933	3.6	May 1	146	193
22	1,901	3.4	2	146	191
23	2,980	5.3	3	144	195
24	1,933	4.4	4	146	196
25	1,838	3.7	5	146	192
			Correlation Coefficient	0.039	0.007

*Mansfield Dam (LCRA data).

**At Loop 360 (USGS data).

***At Davis Water Treatment Plant (City of Austin data).

TABLE 8

WATER QUALITY DURING THE MEMORIAL FLOOD PERIOD WITH MODERATE DAM DISCHARGES AND HIGH CREEK FLOWS

MAY 24 – JUNE 2, 1981

CONDITION 4

Discharge (cfs)			Water Quality*** (mg/l)		
Date	Dam*	Bull Creek**	Date	Alkalinity	Hardness
May 24	2,242	624	June 3	150	196
25	484	540	4	150	195
26	1,896	38	5	150	195
27	2,313	25	6	150	198
28	2,285	19	7	150	190
29	2,039	16	8	150	190
30	1,798	31	9	150	190
31	2,045	27	10	150	190
June 1	2,479	19	11	150	190
2	1,607	18	12	150	190
			Correlation Coefficient	0.000	0.259

*Mansfield Dam (LCRA data).

**At Loop 360 (USGS data).

***At Davis Water Treatment Plant (City of Austin data).

MEAN MONTHLY TOTAL ALKALINITY VALUES FOR RAW INFLUENT WATERS AT AUSTIN WATER TREATMENT PLANTS DURING 1976 TO 1980

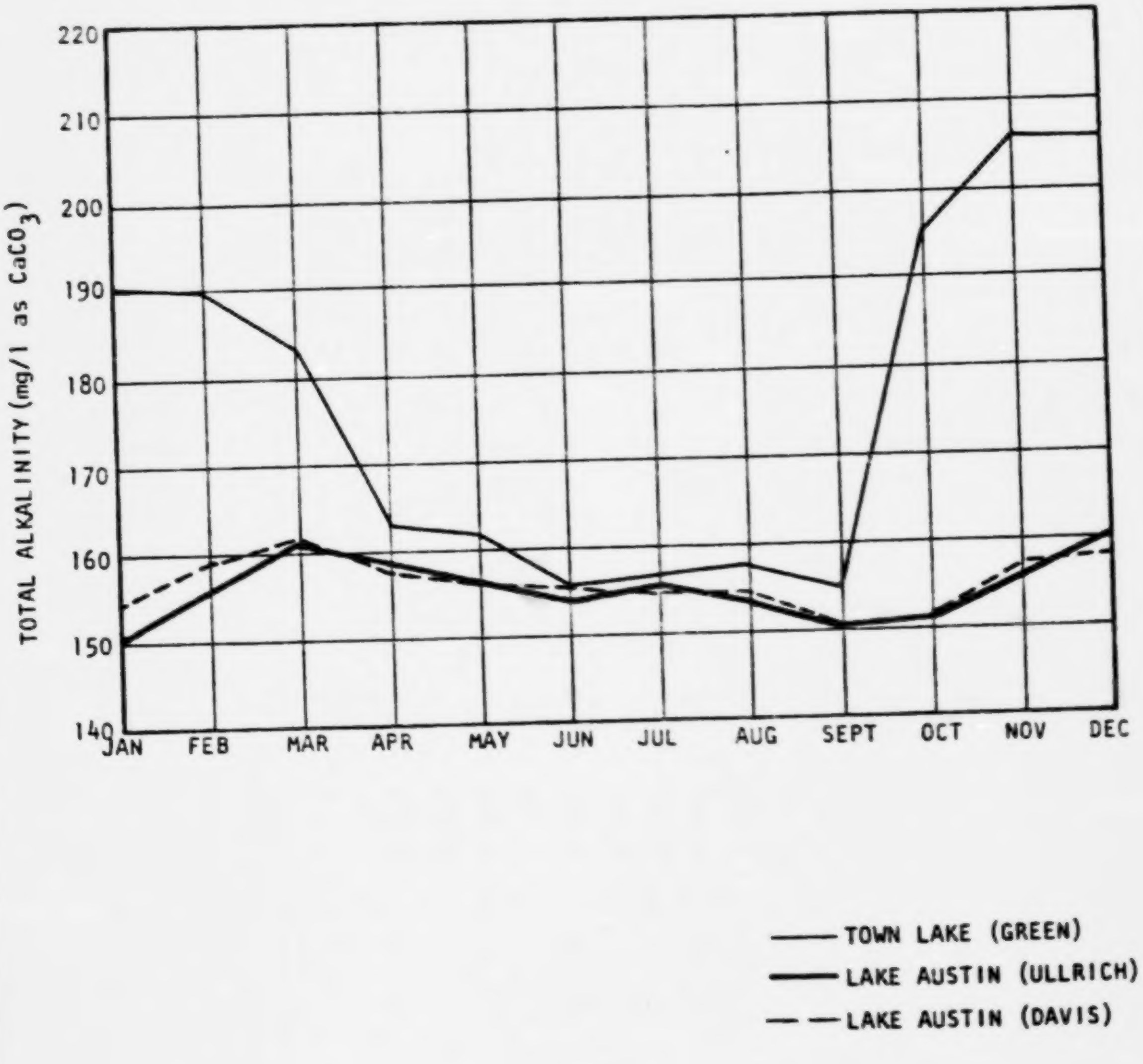


FIGURE 6

MEAN MONTHLY TURBIDITY VALUES FOR RAW INFLUENT WATERS AT AUSTIN WATER TREATMENT PLANTS DURING 1975 TO 1980

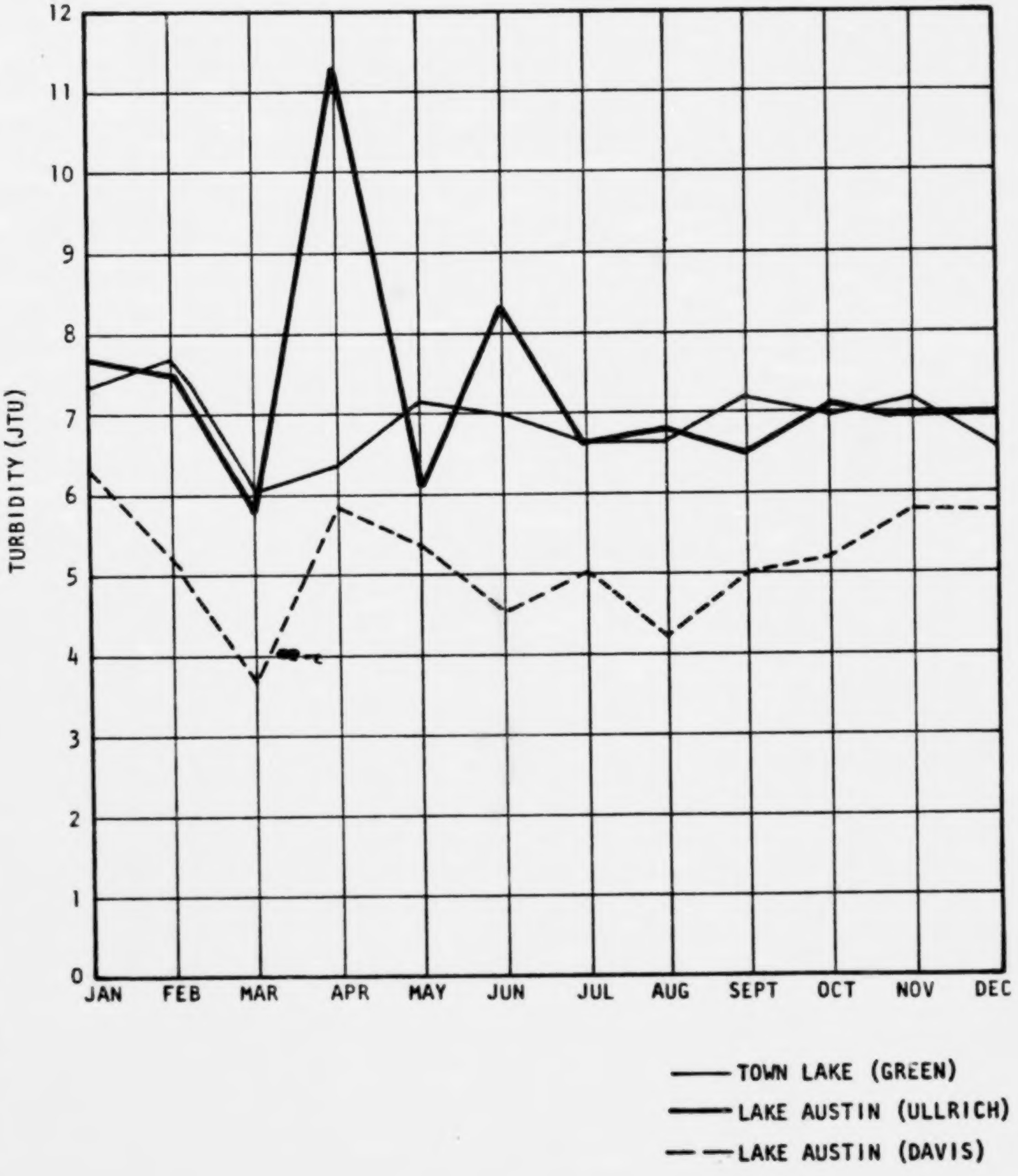
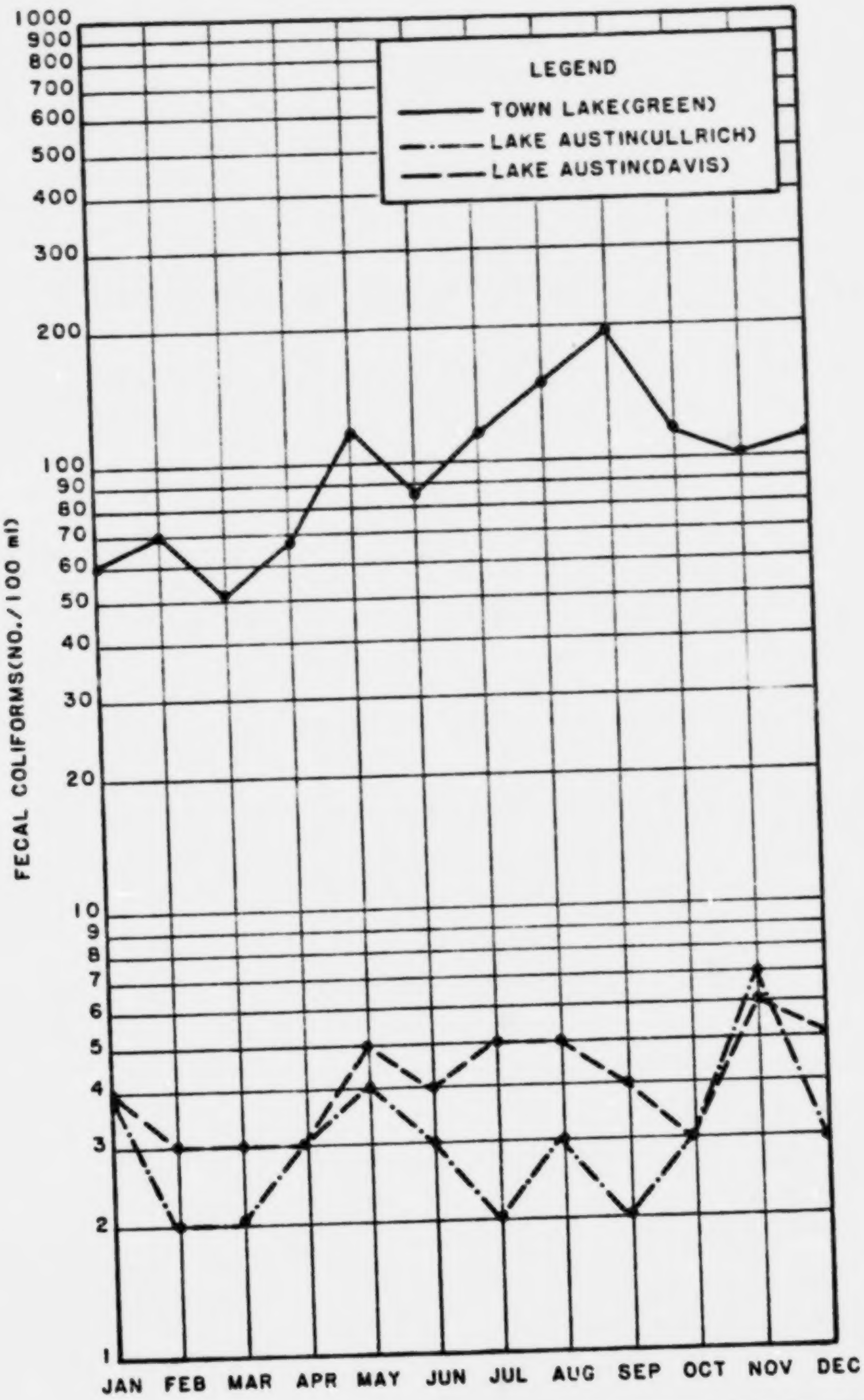


FIGURE 7

GEOMETRIC MEAN MONTHLY NUMBERS OF FECAL COLIFORMS IN RAW INFLUENT WATERS AT AUSTIN WATER TREATMENT PLANTS DURING 1978-1980



that there exists an apparent water quality difference between the waters of the two impoundments as measured at the intake of the water treatment plants. Major water quality differences are obvious for each of the aforementioned parameters, although the most significant differences are characterized by the levels of fecal coliforms in the two lakes. Generally, turbidity measurements exhibited transient increases after storm events, and the magnitude of runoff-generated turbidity was more pronounced in Town Lake than Lake Austin.

Event-oriented water quality data (as collected by the USGS) for the level of fecal coliforms present in Town Lake following a rainfall are presented in Table 9 for three lake sampling stations. These data record the apparent impact of urban runoff contributions from Shoal and Waller Creeks on the water quality of Town Lake. Similar event-oriented water quality data are presented in Table 10 for the fecal coliform concentrations found in the waters of Lake Austin as measured at the intake of the Davis Water Treatment Plant. These data seem to indicate that a probable rise in the fecal coliform level of Lake Austin does, in fact, occur during a storm water runoff event.

The evaluation of the historical data record with regard to the level of pesticides and heavy metals in the receiving waters indicate that few of these materials are detectable in the water column of Lake Austin and Town Lake, and those that do occur are not found in concentrations that might be harmful to aquatic life and/or the beneficial uses of the water supply. (In other words, these concentration levels do not appear to limit or favor the population distribution of any particular species of plants or animals that live in the reservoirs. They also have no apparent impact on the survival levels or growth rates of the resident aquatic life.) It is possible, however, that the water quality surveys which comprise the historic record for the presence of toxic pollutants in the two impoundments did not coincide with runoff events, and that the concentration of these pollutants was rapidly attenuated in the water column by dilution with the discharges from Lake Travis. Moreover, since many of these toxic materials often are insoluble in water as well as being associated with suspended materials in the water column, it is possible that significant levels of metals and toxic organics may exist in the sediments of the two lakes. The Austin NURP study undertook a comprehensive survey of lake bottom sediments and aquatic life in order to assess these premises, and these data are presented herein.

TABLE 9

USGS ANALYSES OF FECAL COLIFORM CONCENTRATIONS IN TOWN LAKE FOLLOWING RAINFALL EVENTS

Date of Sample	Fecal Coliform Colonies per 100 ml			Number of Days Between Sampling Date and Previous Rainfall	Previous Rainfall Depth (inches)
	Tom Miller Dam	Lamar Boulevard	Longhorn Dam		
2/03/75	60	120	460	0	0.7-0.9
6/12/75	84	140	290	2	0.3-1.0
8/12/75	6	69	72	8	0.1-0.9
1/06/76	9	88	16	13	1.0-1.7
4/20/76	240	960	2,500	2	2.8-5.2
9/01/76	8	10	520	0	0.0-0.5*
9/02/76	7	680	2,800	0	1.0-2.1
12/28/76	6	57	12	9	0.1-0.2
4/26/77	6	16	16	6	0.3-0.5
8/23/77	7	9	53	12	0.1-0.4
12/29/77	9	540	52	0	0.1-0.2**
4/10/78	280	2,800	3,800	0	1.2-2.6
7/18/78	4	38	84	40	0.1-0.4
10/16/78	20	31	6	13	0.0-0.4
2/07/79	9	39	64	1	0.3-0.5
5/29/79	16	140	180	1	0.1-0.2
8/22/79	8	37	120	3	0.1-0.2
7/27/79	680	9,900	12,000	0	4.0-4.4
3/03/80	6	82	8	3	0.1-0.3
3/28/80	220	4,600	2,000	1	2.8-2.9
5/19/80	44	140	200	1	0.1-0.2

*Rainfall occurred only in East Austin.

**0.2 inches of rain also had fallen on 12/28/77.

TABLE 10

FECAL COLIFORM CONCENTRATIONS IN DAVIS WTP INTAKE WATERS FOLLOWING RAINFALL EVENTS

Month of Rainfall Event	Amount of Rainfall (inches)	Fecal Coliform Colonies Per 100 ml			
		Day Prior to Rainfall	Day of Rainfall Event	Day After Rainfall Event	Two Days After Rainfall Event
April, 1976	3.39	*	210	120	116
May, 1976	1.82	5	5	120	80
September, 1977	1.38	*	50	36	140
November, 1977	1.08	2	6	8	*
May, 1978	1.10	14	34	*	*
June, 1978	3.36	2	3	46	32
July, 1978	0.86	4	36	40	11
January, 1979	1.35	24	16	12	*
May, 1979	4.08	*	2	58	63
May, 1980	1.14	2	6	14	*
May, 1980	1.42	*	31	16	12

* No fecal coliform sample taken. Normal laboratory procedures at the Davis water treatment plant only permit coliform enumeration on Monday through Thursday of normal work week.

SITE SELECTION AND INSTRUMENTATION

The NURP sampling sites were selected according to the objectives of the study and their relative effectiveness in generating data for use in the evaluation of a nonstructural control measure, namely, percent of impervious cover. Three watersheds in Northwest Austin, Rollingwood, and Turkey Creek were chosen for the storm water sampling sites, whereas two lakes, Lake Austin and Town Lake, were used in the receiving water evaluation.

STORM WATER STUDY

Site Description

In order to thoroughly document low-to-medium-density residential storm water runoff water quality, the specific storm water sampling sites were selected according to how well they characterized this nonstructural control measure.

Sampling Areas to Test the Nonstructural Control Measure

Candidate watersheds for storm water runoff quantity and quality sampling were selected in order to test and compare the effectiveness of a specific type of nonstructural runoff control measure. The sampling program was designed to assess the apparent impact of this nonstructural control measure on storm water runoff quality. The density of development expressed as percent of impervious cover was utilized for selection of two study watersheds exhibiting primarily low-to-medium-density residential development. These two watersheds each feature a distinct level of impervious cover, but are basically similar with respect to other physiographic features. An undeveloped area in the Lake Austin watershed also was monitored for comparative baseline data. This area was selected as a control, and it serves to typify the runoff characteristics of a relatively undisturbed physiographic condition. All the test watersheds are characteristic of the general physiographic condition of the Lake Austin watershed.

The three selected watersheds range in area from 60 acres to approximately 1,300 acres. They are located in both the Lake Austin and Austin urban areas, and their soils have the profile representative of the Brackett Association. The characteristics of the selected storm water study sites are indicated in

Table 11. The Northwest Austin site, which typifies a high impervious cover residential condition, is located within the Shoal Creek watershed which is a tributary to Town Lake. The Rollingwood site, which serves to typify a low impervious cover residential development, is located adjacent to Town Lake. The Turkey Creek site drains directly to Lake Austin and acts as a control providing runoff quality data on a relatively undisturbed watershed.

The Northwest Austin site is characteristic of a density of development of approximately one house per quarter to one-third acre, while the Rollingwood site is characteristic of a density of one house per three-quarter to one acre. The Rollingwood site development incorporates the use of septic tanks for sewage disposal, while the Northwest Austin site is connected to the City sewerage system. The Northwest Austin, Rollingwood, and Turkey Creek sites are depicted in Figures 8, 9, and 10, respectively. Their location with respect to both Town Lake and Lake Austin were depicted in Figures 3 and 4, respectively.

In selecting the three test watesheds for the program, an effort was made to maximize the homogeneity of physiographic features between areas such that all these areas are characteristic of the Lake Austin watershed. This permits the isolation of the effects of urban development on storm water runoff quantity and quality and allows thorough evaluation of their associated impacts.

Sampling Areas to Test the Structural Control Measure

The study evaluated the effectiveness of a storm water detention basin in controlling urban runoff quality. Traditionally, such detention ponds have been designed and built within the City of Austin primarily for runoff quantity attenuation. This program, however, emphasizes an evaluation of the potential for runoff quality control using detention ponds. Austin, like many other cities, relies on detention ponds to meet ordinance requirements related to storm water runoff quality standards which would justify a thorough evaluation of their performance.

The Woodhollow Dam storm water drainage detention facility was selected as the detention basin runoff control structure to be examined during the Austin NURP study. This detention pond is located within the Shoal Creek Drainage Basin and is contiguous with the Northwest Austin site as depicted in Figure 8. The inlet to this detention pond coincides with the storm water

TABLE 11

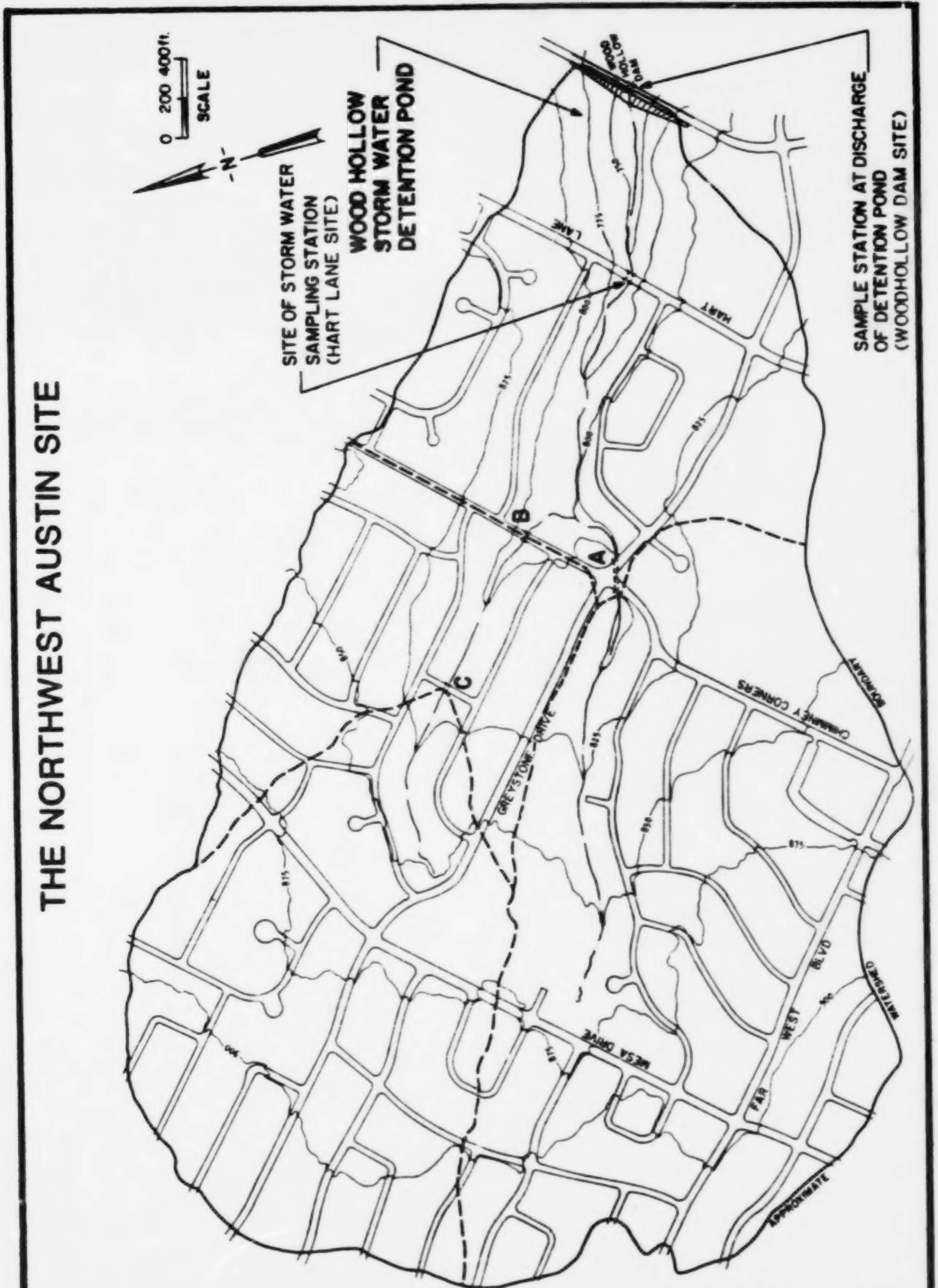
CHARACTERISTICS OF SELECTED STORM WATER STUDY SITES

Item	Site		
	Northwest Austin* (Medium-Density Residential)	Rollingwood (Low-Density Residential)	Turkey Creek (Virgin)
Area of Housetops and Driveways (acres)	101.86	6.31	-
Paved Roads** (acres)	46.33	6.57	-
Total Watershed Area (acres)	377.71	60.21	1,297.0
Weighted Runoff Curve Number	79	78	75
Total Impervious Cover (percent)	39.23	21.39	1.0
Slope of Watershed Channel (percent)	2.60	6.90	1.90
Overland Flow Slope (percent)	4.60	5.90	7.5
Street Surface Gutter Slope*** (percent)	3.5	2.5	-
Estimated Time of Concentration (hours)	0.53	0.23	1.92

*Northwest Austin site includes entire Wood Hollow Dam watershed.

**Street surface paved with shallow curbs and gutters.

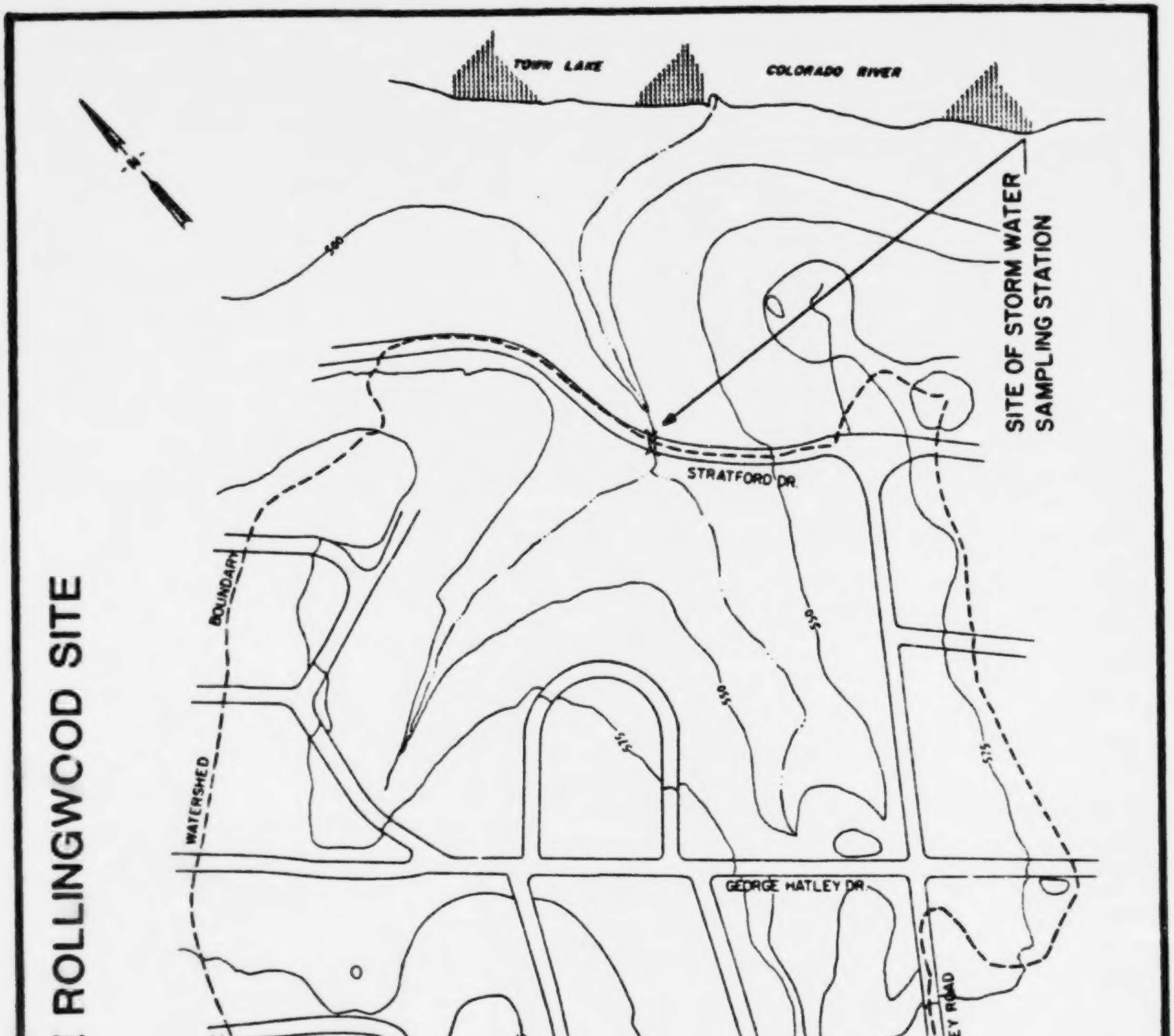
***Numerous underlying storm drains which drain to watershed channel.



THE NORTHWEST AUSTIN SITE

SITE OF STORM WATER SAMPLING STATION (HART LANE SITE)
WOOD HOLLOW STORM WATER DETENTION POND
SAMPLE STATION AT DISCHARGE OF DETENTION POND (WOODHOLLOW DAM SITE)
N
0 200 400 ft.
SCALE
WOOD HOLLOW DAM
HART LANE
GREYSTONE DRIVE
CHIMNEY CORNERS
MESA DRIVE
FAR WEST BLVD
APPROXIMATE WATERSHED BOUNDARY
A
B
C
775
800
825
850
875
900

FIGURE 9

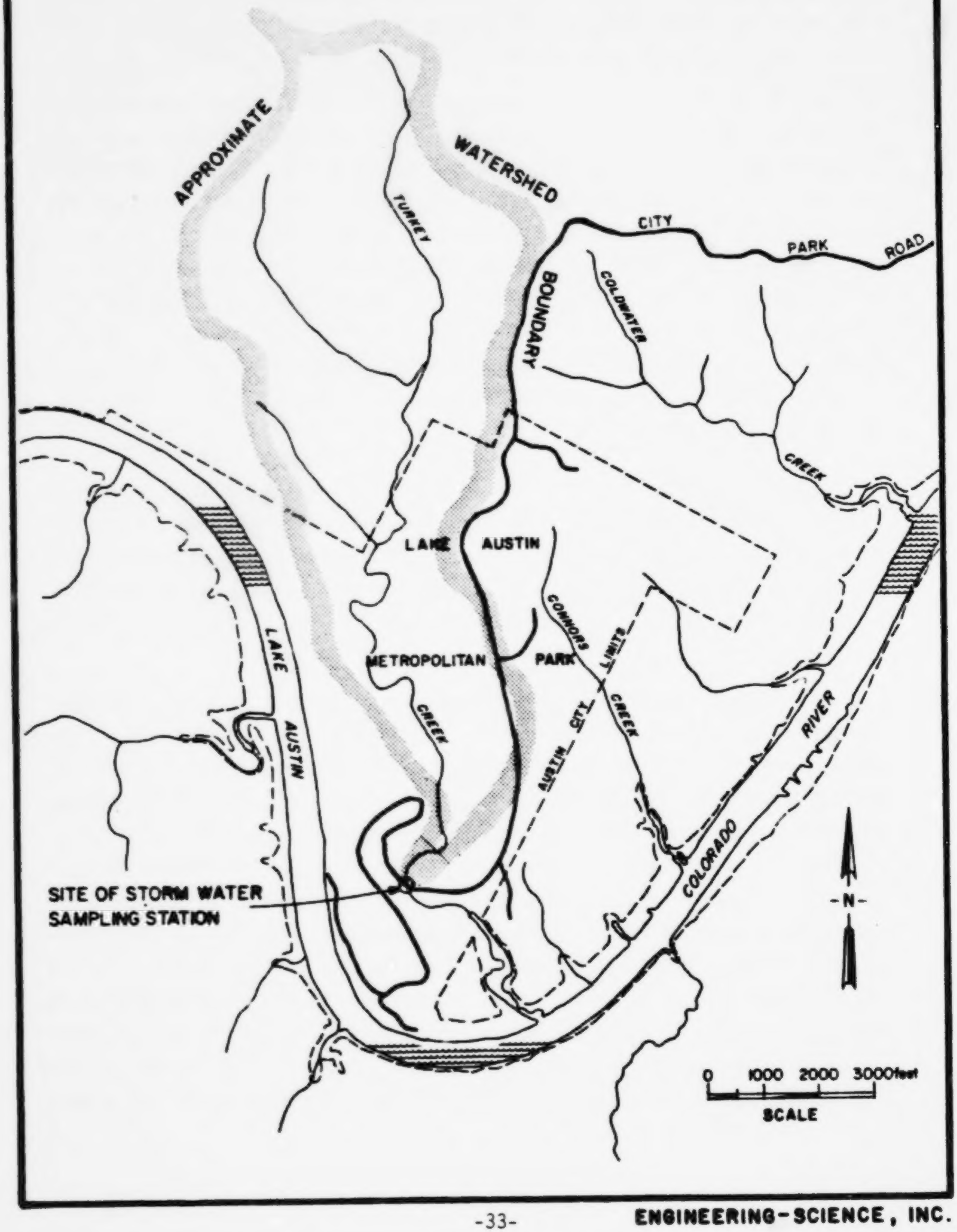


THE ROLLINGWOOD SITE

TOWN LAKE
COLORADO RIVER
SITE OF STORM WATER SAMPLING STATION
STRATFORD DR.
GEORGE HATLEY DR.
RILEY ROAD
ROLLINGWOOD DR
APPROXIMATE WATERSHED BOUNDARY
500
525
550
575
600
625
650
0 100 200feet
SCALE

FIGURE 10

THE TURKEY CREEK WATERSHED



APPROXIMATE
WATERSHED
BOUNDARY
TURKEY
CITY
PARK
ROAD
COLDWATER
CREEK
LAKE AUSTIN
CONNORS
CREEK
METROPOLITAN
PARK
CREEK
AUSTIN CITY LIMITS
LAKE
AUSTIN
COLORADO
RIVER
SITE OF STORM WATER
SAMPLING STATION
-N-
0
1000
2000
3000feet
SCALE

quantity and quality sampling station used to monitor the Northwest Austin site. To properly evaluate the effectiveness of this structural control site with regard to storm water treatment, the quantity and quality of the storm water was monitored at both the inflow and outflow points of this basin.

The Woodhollow Dam has a maximum storage capacity of approximately 50 acre-feet and provides detention for the storm water drainage from the different subareas which characterize the Northwest Austin site. Data which describe these subareas are presented in Table 12. These data indicate the physiographic and land use characteristics of the Woodhollow Dam drainage area, and provide the basis for the evaluation of this detention basin. Moreover, since the Northwest Austin site is characteristic of a higher density residential development than the Rollingwood site, the evaluation of the Woodhollow storm water detention basin provides insight into the effectiveness of such control structures in reducing nonpoint source pollutant loads from residential areas.

Rainfall Monitoring

During the course of the Austin NURP study, each monitored storm event utilized rainfall data obtained from Austin NURP rain gauges located in each study watershed and/or USGS rain gauges located in the general vicinity of the test watersheds. The locations of both the Austin NURP rain gauges and the USGS rain gauges used during the study are depicted in Figure 11.

The average rainfall for each event over the entire study watershed was calculated using a distance weighting factor which gave higher weight to the precipitation values from those rain gauges located closer to the center of the subject watershed. During some of the storm events, a certain number of the gauges were out of operation, which made it necessary to change these distance weighting factors according to the number of gauges actually in operation. In all cases, the sum of the distance weighting factors used for a particular watershed relative to a given storm event was equal to 1.0. The data presented in Table 13 describes the distance weighting factors used during the study for all combinations of functional rain gauges encountered. These weighting factors were used as follows: rainfall data were collected for a given storm event, and the rainfall at each functional gauge was multiplied by its respective distance weighting factor. Weighted rainfall values for all gauges

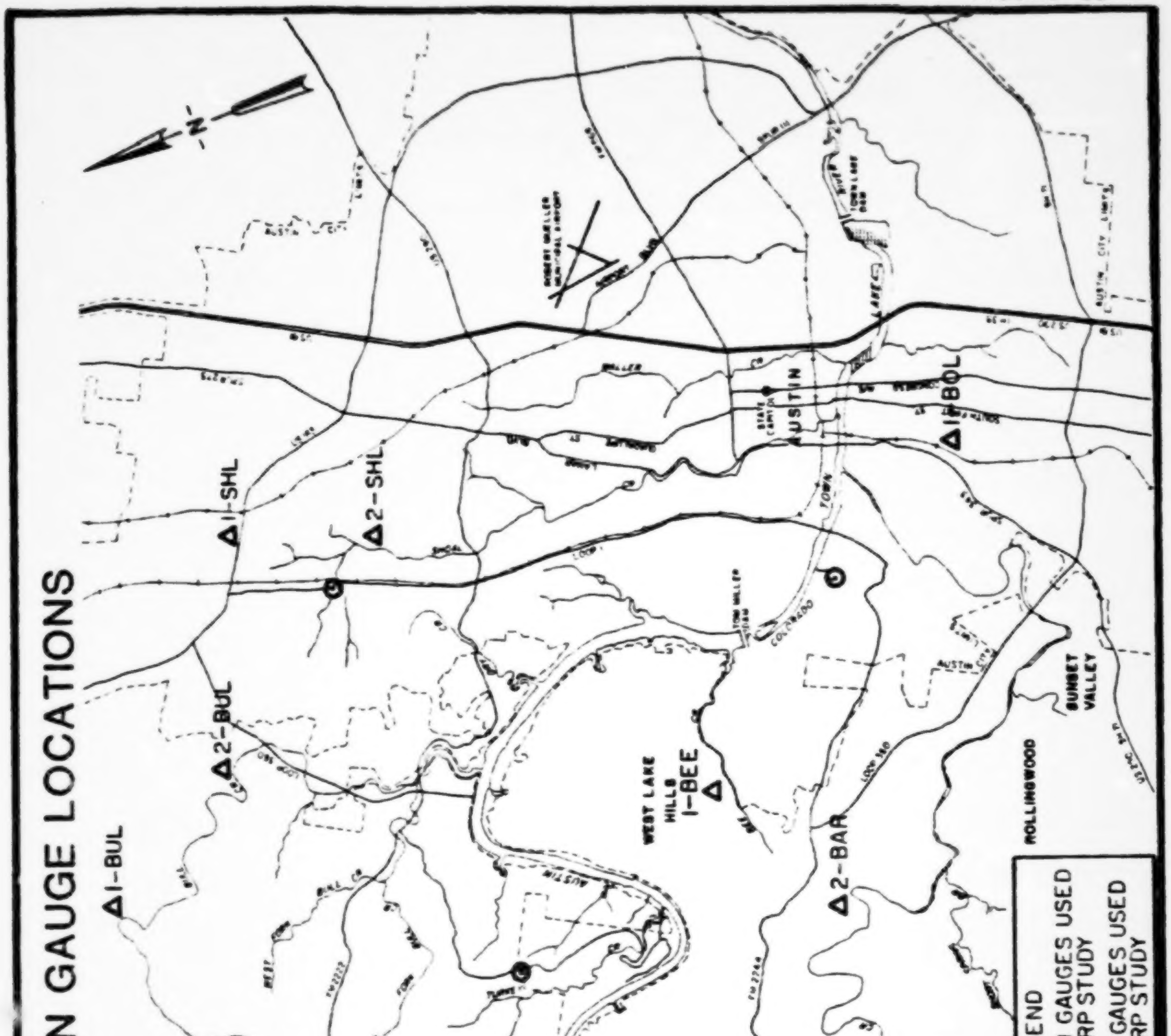
TABLE 12

SUBWATERSHED CHARACTERISTICS AT NORTHWEST AUSTIN SITE

Item	Subwatershed		
	A	B*	C
Area of Housetops and Driveways (acres)	38.90	41.05	27.54
Paved Roads (acres)	15.99	20.24	14.18
Total Subwatershed Area (acres)	150.09	144.64	98.93
Weighted Runoff Curve Number	79	80	80
Total Impervious Cover (percent)	36.57	42.37	42.17
Slope of Subwatershed Channel (percent)	3.1	3.4	3.3
Overland Flow Slope (percent)	4.4	3.0	3.0
Street Surface Gutter Slope (percent)	4.0	2.9	2.9
Estimated Time of Concentration (hours)	0.19	0.19	0.16

*Subwatershed B includes subwatershed C.

FIGURE 11


RAIN GAUGE LOCATIONS

N
1-BUL
2-BUL
1-SHL
2-SHL
WEST LAKE HILLS
1-BEE
2-BAR
AUSTIN
1-BOL
ROLLINGWOOD
SUNSET VALLEY
BEE CAVE
LAKE AUSTIN
COLORADO
TOWN LAKE
LAKE TRAVIS
ROBERT MUELLER MUNICIPAL AIRPORT
STATE CAPITOL
AUSTIN CITY LIMITS
LEGEND
△ USGS RAIN GAUGES USED DURING NURP STUDY
⊙ NURP RAIN GAUGES USED DURING NURP STUDY
0
1
2 mile
SCALE

ENGINEERING-SCIENCE, INC.

TABLE 13

DISTANCE WEIGHTING FACTORS USED FOR OPERATIONAL NURP AND USGS RAIN GAUGES

Rain Gauge	Weighting Factors*			
Northwest Austin Watershed				
1 SHL	0.130	0.263	-	-
2 SHL	0.222	0.448	0.608	0.256
2 BUL	0.143	0.289	0.392	0.164
NURP	0.505	-	-	0.580
Sum of Factors	1.000	1.000	1.000	1.000
Rollingwood Watershed				
1 BOL	0.038	0.390	0.032	
1 BEE	0.032	0.336	0.028	
2 BAR	0.026	0.274	-	
NURP	0.904	-	0.940	
Sum of Factors	1.000	1.000	1.000	

*If a gauge was not operational, it does not have a value for the weighting factor.

used in a particular watershed were summed to obtain an average rainfall over the entire watershed for that particular event. These rainfall values were used to assess the level of precipitation associated with a given storm event.

Modifications to Equipment

The four urban runoff monitoring sites each utilized a water level meter with recorder to measure discharge and to drive one or two storm water quality samplers at any given time. The samplers were designed to operate through the water level meters, thus the water level meters were the "backbone" of the equipment at each of the monitoring sites.

Three of the sites utilized the Manning UTL 2102A ultrasonic level transmitter (with recorder) as their water level measurement device. This device sends out ultrasound pulses through a transducer and measures the time required for the pulses to return to the transducer. This time was compared to a "zero" time and was digitized in the meter which then converted the digitized time to level (in percent of maximum depth). The UTL 2102A which was used in this program was designed to drive one or more Manning samplers (Model S4040) when the water surface reached a predetermined level and tripped an alarm in the level meter. As long as the water surface remained at or above this level, the sampler continued to operate.

When the program began, it was envisioned that each UTL 2102A would drive one Manning sampler which would monitor the "conventional" pollutants. Toxic organics and heavy metals would be monitored by two ISCO model 2100 samplers which would be rotated between three sites (Rollingwood, Hart Lane, and Woodhollow Dam). The ISCO samplers would be tripped by an ISCO model 1640 liquid level sampler actuator (basically a conductivity probe which closes a circuit when the water surface reaches the probe tip to trip the sampler). When the equipment was put into the field, it was discovered that at one site, the cable on the 1640 actuator was not long enough to reach from the instrument shelter to the water surface. It also was discovered that the actuators would be subject to damage by floating debris during intense storms. Hence, it was necessary to come up with another way to drive the ISCO 2100 samplers.

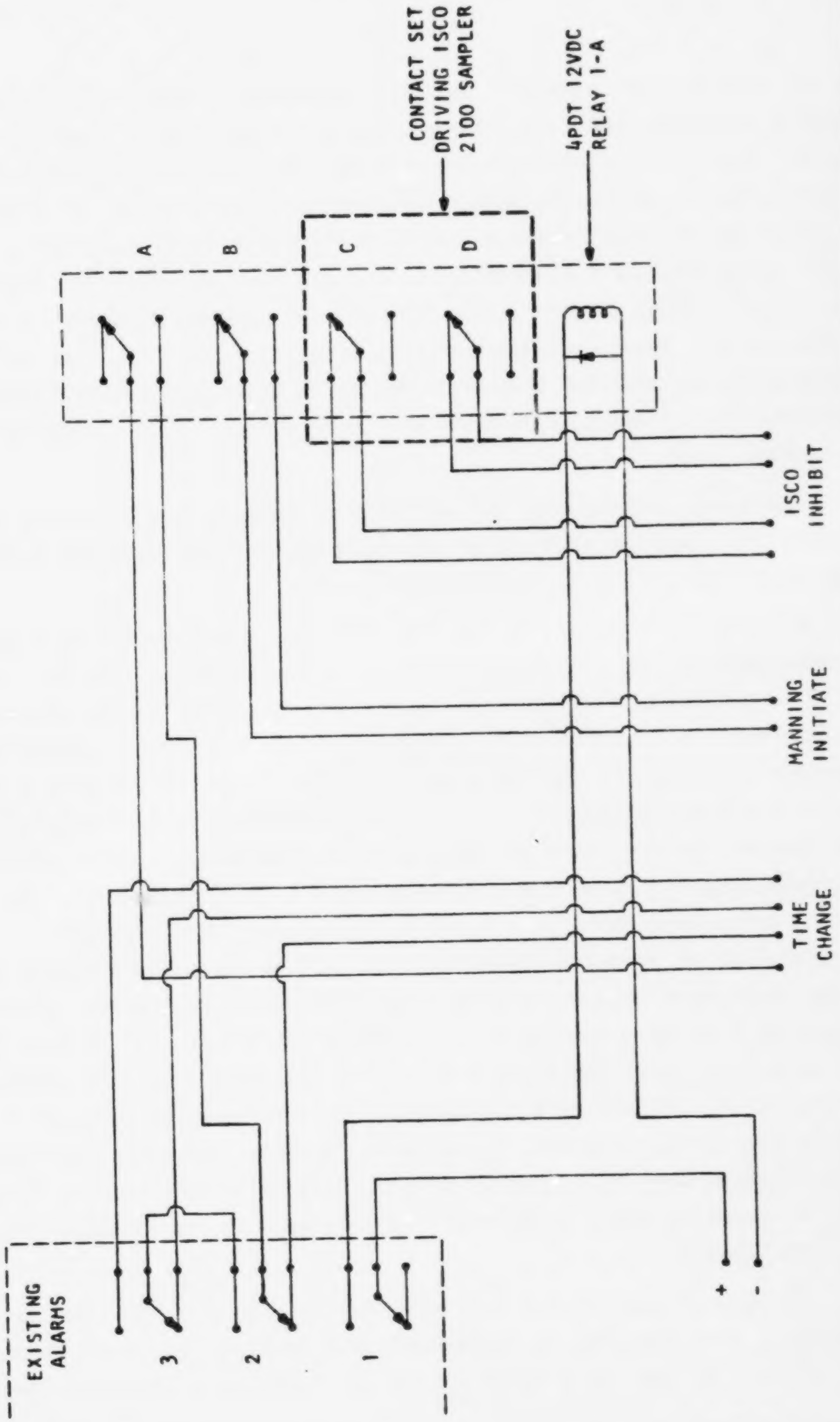
The level alarm on the Manning model UTL 2102A level transmitter is basically a contact set which is normally closed. When the water surface reaches the alarm level, this contact set opens, initiating a sampling sequence in the Manning S4040 sampler. The S4040 continues to sample as long as the contact set remains open (e.g., the water surface remains at or above the alarm level). The ISCO model 2100 sampler is tripped by a contact closure instead of a contact opening as for the S4040. The first modification of the UTL 2102A was to add a second contact relay to the first alarm level which is normally open. Hence, an ISCO 2100 and a Manning S4040 may both be driven simultaneously from the first alarm on the UTL 2102A. Driving two samplers from the UTL 2102A allows closer control of the sampling program at each site as well as eliminating the need for a separate device to drive the ISCO 2100 sampler. Figure 12 is a schematic of the above modification plus all other modifications to the UTL 2102A.

The above modification proved very successful, and by adding extra relays, any number of ISCO and/or Manning samplers could be driven from the same level meter.

A second modification to the UTL 2102A level transmitter involved the Manning S4040 sampler. It was felt that a more representative sampling program could be conducted if the interval between samples could be changed during the storm event. As the flow rate increased, the interval between samples would increase enabling the equipment to catch the "first flush" with a short interval between samples, but conserving sample collection bottles by spacing the samples further apart as the flow rate increased. This modification involved using all three level alarms on the UTL 2102A, each with a separate wire in a four-wire cable. The fourth wire is a power wire which activates the system. Each of these four wires has a pin jack on the end of the wire which plugs into a receptacle on the side of the S4040 sampler control box. There are a total of 12 of these receptacles on the S4040 control box. Ten of these jacks are color-coded blue and represent sampling intervals from 3.75 minutes to 24 hours with each jack representing a specific time interval. One jack is red and is used for the power wire in the four-wire cable. The other jack is white and allows the sampler to be returned to its original single sampling interval mode of operation when a jumper wire is run between the red and white jacks on the S4040 control box.

The mode of operation of this modification is as follows: the operator selects a time interval to correspond with each of the level alarms on UTL 2102A. If the first alarm is to correspond to a 15-minute sampling

MODIFICATIONS TO MANNING UTL -2102A ULTRASONIC LEVEL METER


CONTACT SET DRIVING ISCO 2100 SAMPLER
4PDT 12VDC RELAY 1-A
A
B
C
D
ISCO INHIBIT
MANNING INITIATE
TIME CHANGE
EXISTING ALARMS
3
2
1
+
-

interval, he inserts the pin of the wire corresponding to the first alarm (each wire is a different color) into the jack which represents the 15-minute interval on the S4040. The same procedure applies to the other two alarms. The red power wire is inserted into the red jack. Now, when the water level rises to the first alarm position, the sampler is triggered and begins to sample every 15 minutes. If a further rise to the third alarm occurs, another interval becomes operational until the water drops. At this time the modification is such that the sampling interval drops to that of the second and then the first alarm requiring a manual reset if a longer interval is required.

The main purpose of the modifications was to prevent the excessive use of sample collection bottles if a very large storm occurred, because if there were such a storm, it might not be possible to get to a site and change bottles until the storm abated. Also, it would help to prevent premature battery discharge due to excessive sampling over a long time period. This modification has been made to two of the three S4040 samplers and has been successful. Further investigation of the equipment might yield a way to increase the sampling interval during hydrograph recession without resorting to a manual reset. Figure 13 is a schematic of this modification to the S4040 quality sampler.

An additional modification made to the UTL 2102A level meter was to attempt to waterproof the outer case of the meter. As it came from the factory, the UTL 2102A was designed to allow two cables to pass through the wall of the case and remain water-tight by the use of rubber bushings around the cables. This project required that at least six cables pass through the outer case due to modifications and additional equipment necessary for the study. In order to accomplish this, Amphenol fittings were mounted to the meter case and to the cables running to and from various equipment in order to create an easily disconnected water-resistant fitting on the outside of the meter case. Figure 14 shows a before and after view of this modification to the UTL 2102A level meter.

This modification was successful and provided much-improved serviceability to the UTL 2102A by allowing service personnel to quickly remove the UTL 2102A from the field for service. No tools are required, whereas prior to the modification, it took up to 20 minutes to remove the level meters with screwdrivers and pliers. This modification also protects the electronics of the level meter from water damage such as was suffered by one meter during the flood of May 24, 1981 at the Hart Lane site.

FIGURE 13

MANNING S4040 SAMPLER TIME CHANGE MODIFICATION

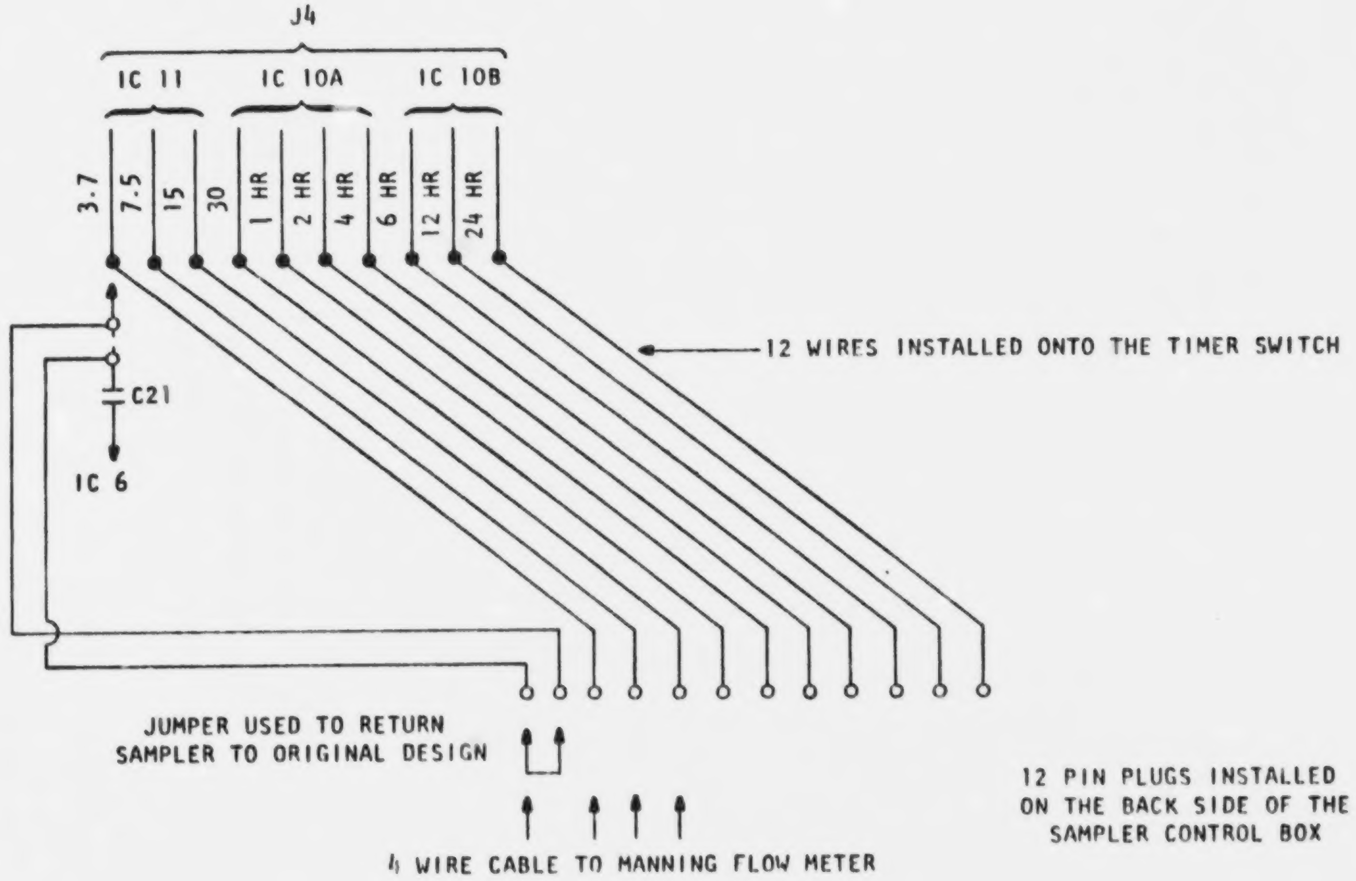
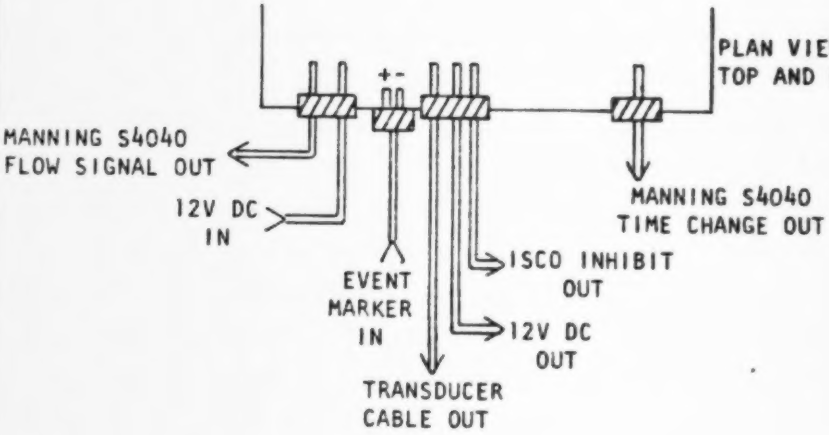

J4
IC 11
IC 10A
IC 10B
3.7
7.5
15
30
1 HR
2 HR
4 HR
6 HR
12 HR
24 HR
C21
IC 6
12 WIRES INSTALLED ONTO THE TIMER SWITCH
JUMPER USED TO RETURN SAMPLER TO ORIGINAL DESIGN
12 PIN PLUGS INSTALLED ON THE BACK SIDE OF THE SAMPLER CONTROL BOX
4 WIRE CABLE TO MANNING FLOW METER

FIGURE 14

MODIFICATIONS TO MANNING UTL 2102A CASE

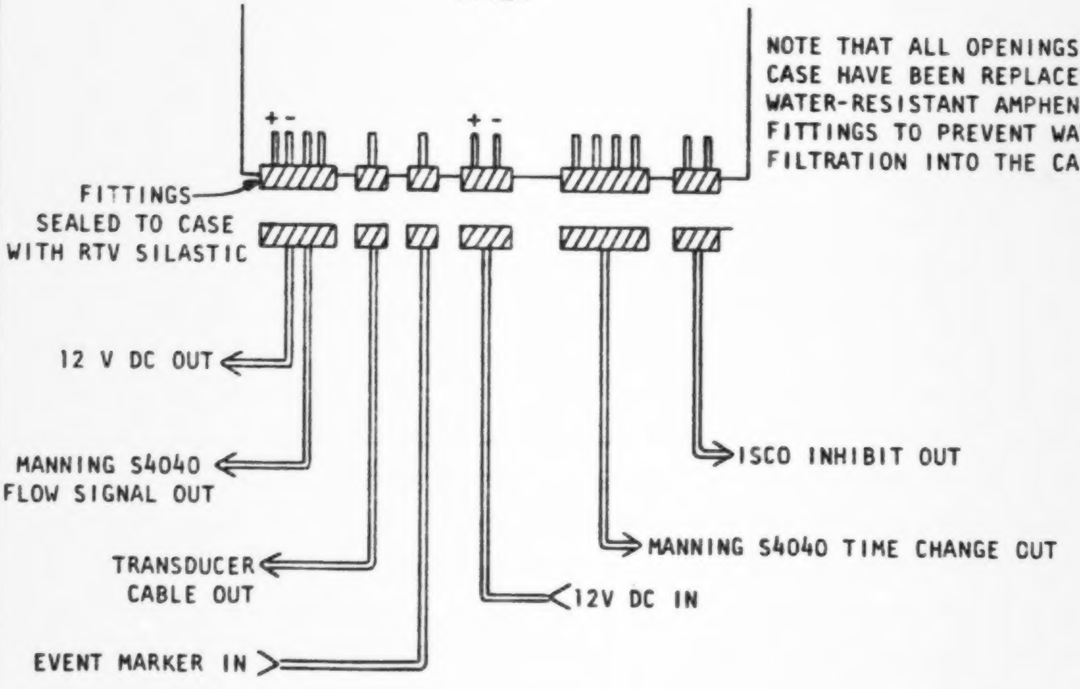
BEFORE


+ -
MANNING S4040 FLOW SIGNAL OUT
12V DC IN
EVENT MARKER IN
TRANSDUCER CABLE OUT
12V DC OUT
ISCO INHIBIT OUT
MANNING S4040 TIME CHANGE OUT

PLAN VIEW OF UIL 2102A CASE WITH TOP AND CIRCUIT BOARD REMOVED.

IN THE ABOVE VIEW TWO OR THREE CABLES PASSED OUT THROUGH A FITTING DESIGNED FOR ONE. BECAUSE THE BUSHINGS IN THE FITTINGS WOULD NOT SEAL WATER OUT OF THE CASE WHEN TWO OR MORE CABLES PASSED THROUGH EACH FITTING, WATER WAS ABLE TO PASS THROUGH THE CASE INTO THE ELECTRONICS.

AFTER


+ -
+ -
FITTINGS SEALED TO CASE WITH RTV SILASTIC
12 V DC OUT
MANNING S4040 FLOW SIGNAL OUT
TRANSDUCER CABLE OUT
EVENT MARKER IN
12V DC IN
MANNING S4040 TIME CHANGE OUT
ISCO INHIBIT OUT

NOTE THAT ALL OPENINGS IN THE CASE HAVE BEEN REPLACED WITH WATER-RESISTANT AMPHENOL TYPE FITTINGS TO PREVENT WATER INFILTRATION INTO THE CASE.

One of the three Manning UTL 2102A level meters came from the factory with 12 level alarms instead of the three that the other two meters had. Each of the 12 alarms was designed to both switch on and off as the water surface rose, and then once again switch on and off as it fell. Thus, sampling was to be accomplished according to the actual depth of flow rather than on a timed interval basis. This particular level meter was to be used at the Rollingwood site which utilized an HL-type flume as its hydraulic control. In practice, it was discovered that if the water level rose or fell very rapidly (which did happen most of the time), many samples were collected over a very short period of time which sometimes resulted in all of the collection bottles being filled during the very first part of a runoff event. This situation was remedied by converting the 12-alarm unit back to a three-alarm level meter by disconnecting the upper nine alarms and adding a resistor to each of the lower three. This modification has proven very successful since the problem with many samples being collected in a short period of time has been eliminated. The sampler at Rollingwood was able to operate on a straight-time mode when runoff was occurring.

Two maintenance problems which occurred during the course of the project relate to the Manning UTL 2102A level meter. The first item is that a spark gap on the level meter needed to be periodically cleaned by slipping a small feeler gauge through the gap to remove any built-up carbon. This is especially true and most critical if the transducer is removed from the meter and the meter continued to run for even a short period of time. The spark gap acts as a sort of "fuse" or "circuit breaker" for the electronics if the transducer is not in place and arcing occurs across the gap which causes a carbon "bridge". The carbon buildup needs to be removed before operation can resume. This carbon may also build up during normal operation, but the project has not experienced too much trouble with carbon bridging, although it was found that routine cleaning of the spark gap avoids even the most unlikely problems. The second item of interest is that, contrary to factory literature, the Manning ultrasonic transducers may be repaired when the cable is damaged. This is accomplished by cutting into the threaded section of the transducer body and removing the end of the cable from the transducer printed circuit board. A new copper braid coaxial cable is then soldered to the board in place of the original aluminum braid cable. The new cable is routed through a piece of specially modified one-half-inch-diameter PVC pipe which has a threaded end. The new pipe is attached to the transducer head and is filled with Dow Corning "Silastic" sealant which is allowed to cure. (The "Silastic" sealant makes the device water-tight). The new end is attached to a new cable and the whole assembly is then serviceable. The project has reclaimed six transducers damaged by flood or vandalism in this way. Each new Manning transducer costs about $250, compared to approximately $50 to reclaim a damaged transducer. Figure 15 depicts the repair procedure.

The last equipment modification was to the ISCO model 1870 (bubbler) flow meter. This was a factory modification which allowed the 1870 to be used in conjunction with the model 1640 sampler actuator. The 1870 will lie dormant until the 1640 detects liquid in the channel, at which time both the 1870 and its associated model 2100 sampler switch on and run until the water level recedes. This modification which is depicted in Figure 16 has proved to be very successful.

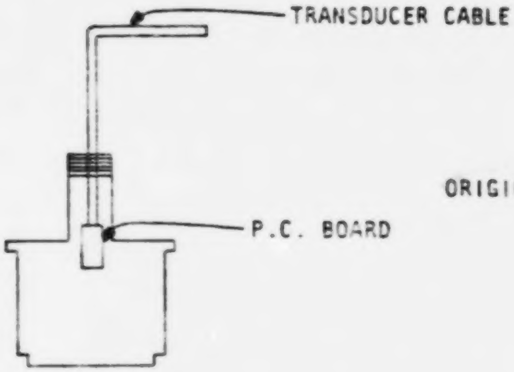
Description of Features Affecting the Monitoring Sites

Urbanization and the physiographical characteristics of the watershed terrain were the major features that appear to affect the runoff quality. The three storm water sampling stations, namely, Hart Lane, Rollingwood, and Turkey Creek, share similar geological terrain which are characterized by soils that are predominated by limestone substrates with a low to moderate infiltration capacity and corrosion potential. These substrates are characteristic of the Lake Austin watershed. For this reason, the features that affect the quality of water sampled at the test stations were the degree of open space and vegetation at a given site as well as the impervious cover. In particular, the Rollingwood and Hart Lane stations which are distinguished by different impervious covers in their respective watersheds had their runoff qualities influenced by the characteristic area foliage. Some minor construction in the Rollingwood and Turkey Creek watersheds may also have had an additional effect on the runoff quality from these sites.

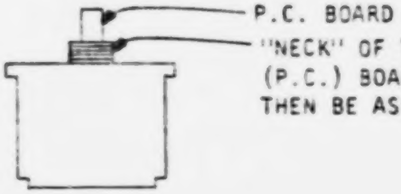
The Woodhollow Dam station, however, appears to have been affected mainly by the hydraulic characteristics of the stream channel. The detention basin was not always full before every runoff event, so runoff was not always monitored downstream of the impoundment at this sampling site because the

FIGURE 15

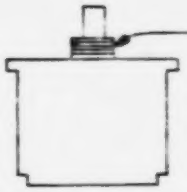
STEPS IN REPAIRING MANNING UTL 2102A TRANSDUCERS


TRANSDUCER CABLE
P.C. BOARD

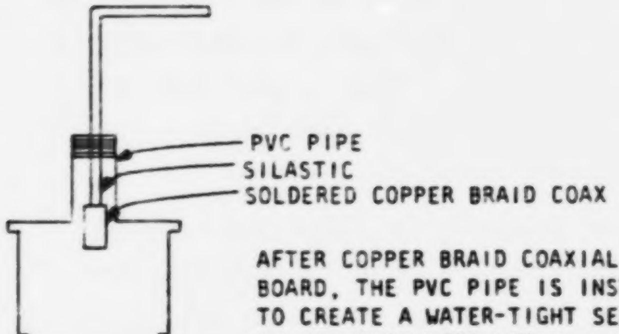
ORIGINAL CONFIGURATION



"NECK" OF TRANSDUCER IS CUT AWAY TO REVEAL PRINTED CIRCUIT (P.C.) BOARD. DAMAGE TO CABLE OR SOLDERED CONNECTIONS MAY THEN BE ASSESSED.

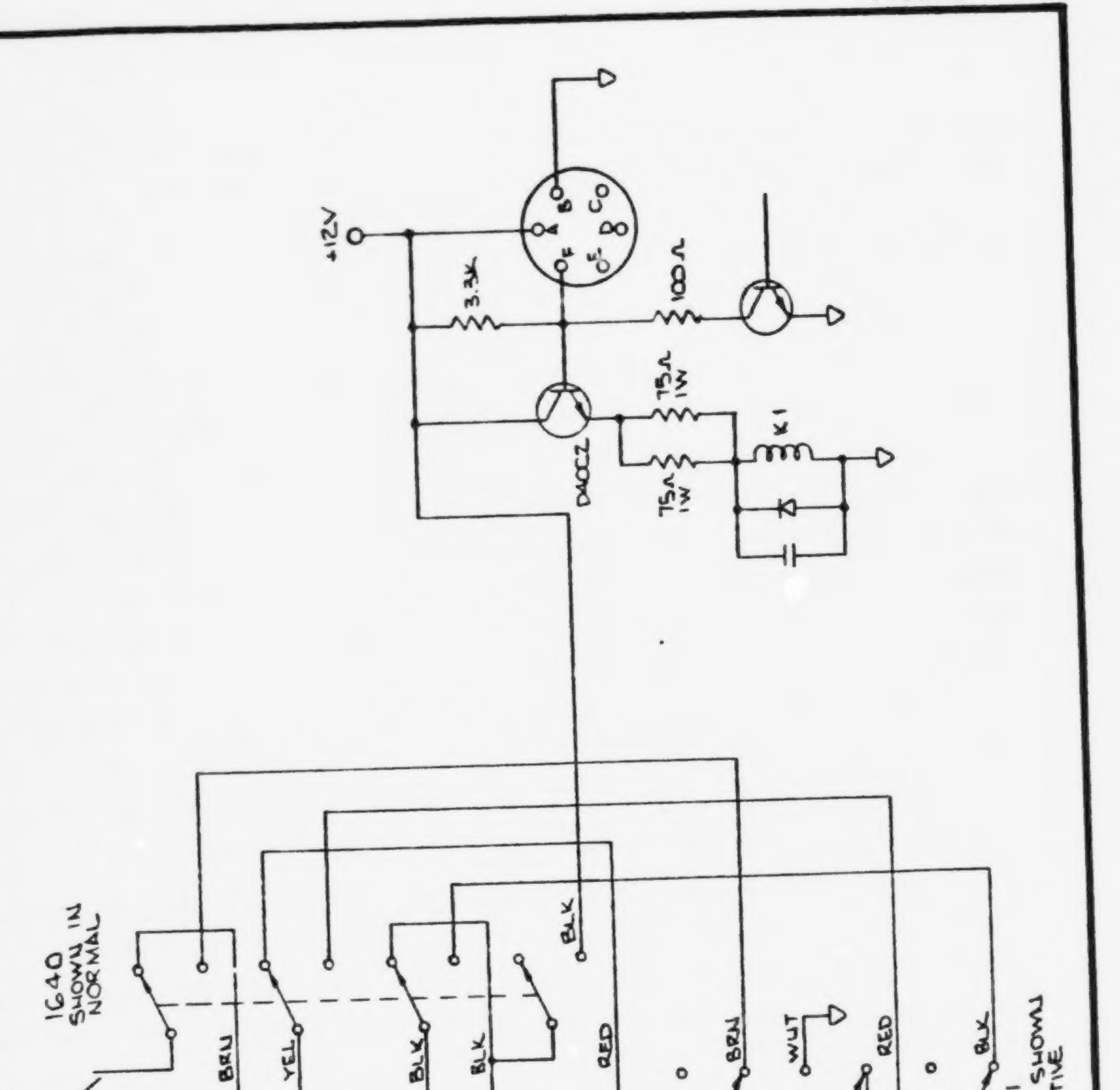


"NECK" IS FITTED WITH THREADS TO ALLOW A SPECIALLY MODIFIED PVC PIPE TO BE INSTALLED ON THE TRANSDUCER. THE PIPE IS MODIFIED BY REAMING IT OUT TO CLEAR THE P.C. BOARD AND OTHER ELECTRONICS IN THE TRANSDUCER.


PVC PIPE
SILASTIC
SOLDERED COPPER BRAID COAX

AFTER COPPER BRAID COAXIAL CABLE IS SOLDERED TO THE P.C. BOARD, THE PVC PIPE IS INSTALLED AND RTV SILASTIC IS USED TO CREATE A WATER-TIGHT SEAL AROUND THE CABLE. TRANSDUCER IS NOW READY FOR USE.

FACTORY MODIFICATION TO ISCO 1870 FLOW METER


+12V
A
B
C
D
E
F
3.3K
100Ω
75Ω 1W
75Ω 1W
K1
DA0C2
1640 SHOWN IN NORMAL
TO STANDBY BATT
+12V TO BOARD
TO LOGIC
BRN
YEL
BLK
BLK
BLK
RED
BRN
WHT
RED
BLK
K1 RELAY SHOWN ACTIVE
FROM STANDBY BATT. CHARGER
WHT
RED
BLK
POWER SHOWN ON
+5V
+12V

detention basin did not fill and overflow a measurable quantity of runoff which would then be monitored at the Woodhollow Dam survey station.

RECEIVING WATER SAMPLING SITES

Site Description

Several Austin NURP receiving water sampling stations were selected on Lake Austin and Town Lake as shown in Figures 17 and 18, respectively. These sampling stations were located primarily in the major tributaries of Lake Austin and Town Lake and were established in order to provide water quality data which accurately reflect the impacts caused by storm water runoff. The mouths of Turkey Creek, Bull Creek, and Dry Creek on Lake Austin and Shoal Creek and Barton Creek on Town Lake were selected as the principal sampling stations because of the greater magnitude of change that their discharges would induce upon the subject receiving water body. Water quality sampling stations were located either along the midchannel axis of the lake or along the middle of the prevailing discharge plume, whichever spatial pattern best described the changing pattern of water quality during a storm runoff event.

Sampling sites were limited to primary lake tributaries, so that the spatial distribution and longevity of runoff flows could be evaluated before they were substantially diluted and dispersed within the lake volume. Points within the lake, both upstream and downstream of the tributaries, were also included in order to isolate and document the effects of runoff flows and transported constituents. Prior to event-oriented sampling, the same sampling sites were utilized during the initial screening survey, which sought to identify areas where water quality, sediments, or fishes might exhibit evidence of runoff-related pollution.

Field Survey Equipment

The receiving water monitoring field survey equipment included the following:

(1) Yellow Springs Instrument Model 51B Dissolved Oxygen Meter with submersible probe (25- and 50-foot cables);

(2) Yellow Springs Instrument Model 33 Conductivity-Salinity Meter with submersible probe (50-foot cable);

LOCATION OF NURP SAMPLING POINTS ON LAKE AUSTIN

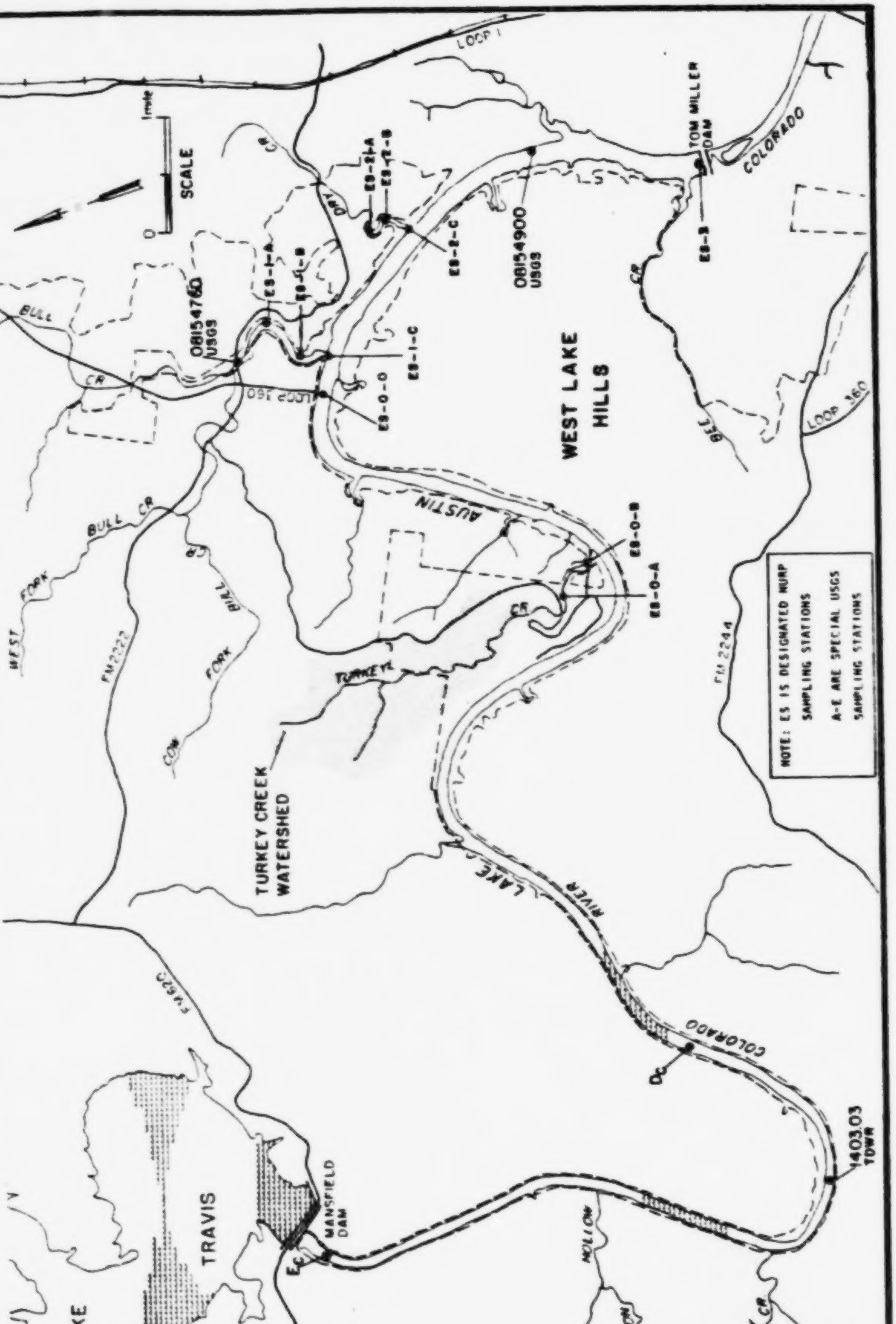
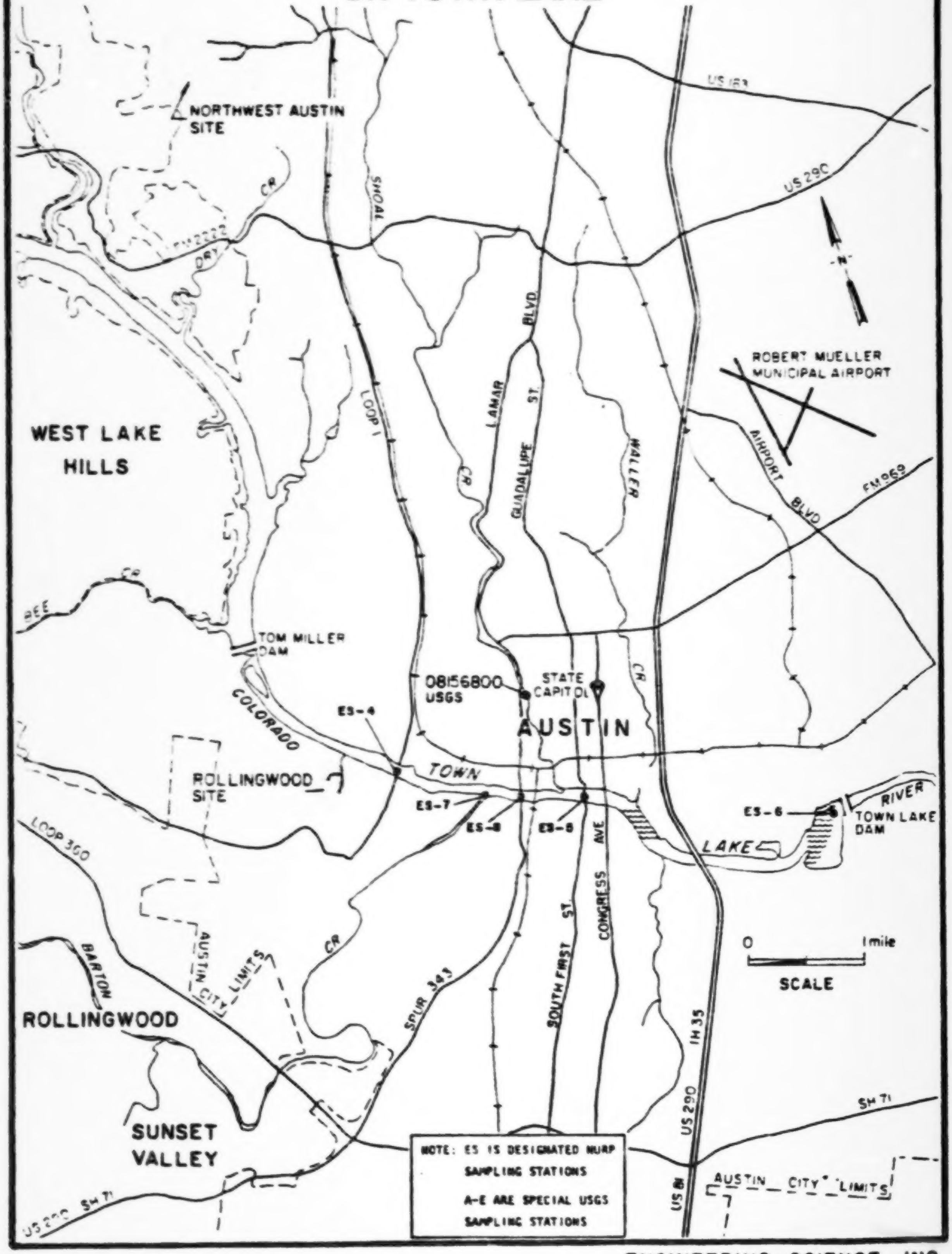

SCALE
0
1 mile
LOOP 1
TOM MILLER DAM
COLORADO
ES-3
08154900 USGS
ES-2-C
ES-2-A
ES-2-B
DRY CR
ES-1-A
ES-1-B
ES-1-C
08154750 USGS
BULL CR
LOOP 360
ES-0-D
WEST LAKE HILLS
BEE CR
AUSTIN
ES-0-B
ES-0-A
WEST FORK BULL CR
FM 2222
COW FORK BULL CR
TURKEY CR
TURKEY CREEK WATERSHED
FM 2244
NOTE: ES IS DESIGNATED NURP SAMPLING STATIONS
A-E ARE SPECIAL USGS SAMPLING STATIONS
LAKE
RIVER
COLORADO
D
FM 620
1403.03 TOWR
LAKE
TRAVIS
MANSFIELD DAM
E
HOLLOW
HARRISON
HANEY CR

FIGURE 18

LOCATION OF NURP SAMPLING POINTS ON TOWN LAKE


NORTHWEST AUSTIN SITE
SHOAL
US 183
US 290
FM 2222
DRY CR
N
LAMAR BLVD
LOOP 1
GUADALUPE ST.
WALLER
ROBERT MUELLER MUNICIPAL AIRPORT
AIRPORT BLVD
FM 969
WEST LAKE HILLS
CR
BEE CR
TOM MILLER DAM
08156800 USGS
STATE CAPITOL
CR
AUSTIN
COLORADO
ES-4
TOWN
ROLLINGWOOD SITE
ES-7
ES-8
ES-5
ES-6
RIVER
TOWN LAKE DAM
LAKE
LOOP 360
AVE
CONGRESS
SOUTH FIRST ST
0
1 mile
SCALE
BARTON
AUSTIN CITY LIMITS
CR
SPUR 343
IH 35
ROLLINGWOOD
US 290
SH 71
SUNSET VALLEY
US 81
AUSTIN CITY LIMITS
US 290 SH 71
NOTE: ES IS DESIGNATED NURP SAMPLING STATIONS
A-E ARE SPECIAL USGS SAMPLING STATIONS

(3) Kahlisco Water Sampler; and
(4) Secchi Disc.

Description of Features Affecting the Monitoring Sites

Similar to the storm water sampling sites, the receiving water quality during a runoff event was affected mainly by the characteristics of the basin terrain and the degree of open space and vegetation, as well as urbanization in the watershed. However, the geological characteristics of the terrain also appear to have a noticeable influence on the receiving water quality.

Lake Austin terrains are characterized by thin soils underlain by mixed limestone substrates with steep slopes. These relatively thin and porous beds are quickly saturated, thus allowing excess fluids to migrate along bedding planes and seep out at the surface. For this reason, the bed rock appears to exert an effect on the storm water runoff quality to a certain extent. Therefore, the receiving water sampling stations that were located in Turkey Creek, Bull Creek, and Dry Creek (three tributaries of different sizes) seem to be affected by these terrain characteristics in a similar manner. However, the apparent impacts from storm water runoff varied according to the degree of watershed urbanization and the characteristic vegetation of the area.

There are two additional sampling stations in Lake Austin that do not seem to be affected by the nature of the bed rock in the area, namely, the stations that are located upstream of Bull Creek and at Tom Miller Dam. These two stations are located in the main pools of the lake and their water quality parameters are, therefore, associated with the upstream water quality, that is, the water quality characteristics of the waters from Lake Travis and Lake Austin proper.

Town Lake terrains are different from those of Lake Austin proper in that they consist of clay, sand, silt, and limestone. However, the upstream portion of Barton Creek is predominated by limestone, unstable clays with continually moving natural slopes and low infiltration rates. These qualities are characteristic of both Barton Creek and Shoal Creek in the Town Lake watershed. Urbanization and development also exert an influence on the quality of storm runoff, and these features appear to have more impact on the water quality in Town Lake than the geographical characteristics of the contributing watersheds.

DATA COLLECTION

TYPES OF DATA COLLECTED

Storm Water Survey

In order to obtain a time-varying flow and water quality data record from the various test watersheds and the storm water control structure examined during the Austin NURP survey, the storm water data record includes the following:

(1) storm runoff data consisting of continuous volume and daily rainfall measurements as well as the water quality of the resultant storm water; and

(2) sampling data for priority pollutants.

The Austin NURP program began monitoring urban runoff events in February 1981, and continued through July. The program monitored a total of 38 events at one or more sites. Table 14 presents a summary of these events showing the location and type of data collected for each event. The majority of the storm events were monitored at both the Hart Lane (Northwest Austin watershed) and the Rollingwood sites and mass loading curves were generated for these watersheds. Quality data for the "conventional pollutant" parameters were obtained from the Turkey Creek (control) watershed for both background and storm event conditions, but due to equipment malfunction and the fact that several floods changed the physical configuration of the channel, meaningful flow data were not obtained from this site.

Receiving Water Survey

Similar to the storm water sampling study, the data collected by the receiving water sampling survey are of two types: (1) screening sampling for a variety of toxic pollutants; and (2) conventional pollutant water quality in the receiving body after a given runoff event.

The background sampling program for Town Lake and Lake Austin was limited to selected pollutant screenings of sediment and fish samples in order to indicate the presence of toxic materials and other constituents which were likely to affect the beneficial uses of lake water. The receiving water study emphasized sampling activities that were closely related to those areas where the maximum useful environmental information on runoff-oriented impacts could

TABLE 14

URBAN RUNOFF EVENTS MONITORED BY STATION
SURVEY YEAR 1981

Event No.	Date	Hart Lane	Woodhollow Dam	Rollingwood	Turkey Creek
01	2/04	F,C	N	N	N
02	2/10	F,C	F,C,O	N	N
03	3/01	C	F,C,O	N	N
04	3/03-04	F,C	F,C,O	N	N
05	3/07	F,C,T	F,C,T	N	N
06	3/12	F,C	F,T	F,C,T	N
07	3/28	F,C	D	F,C,T	N
08	4/17	F,C,T	D	F,C,T	N
09	4/18	(F,C)*	D	(F,C)*	N
10	4/23	F,C,T,PP	D	F,C,M	N
11	4/25	R	R	R	N
12	5/01	E	F,C,M	F,C,T	N
13	5/02	E	F,C,T,	C	F,C
14	5/16	F,C,PP	F,T	F,C,T	N
15	5/24 (early)	F,C,T	F	F,C	R
16	5/24 (late)	FLOOD	FLOOD	F	FLOOD
17	5/30	N,E	N,E	F,PP	N,E
18	6/01	F,C	N	F,C	N
19	6/02	F,C	N	F,C	N
20	6/03	F,C	N	F,E	N
21	6/04	F	N	F,E	N
22	6/05	F	N	F,C	N
23	6/11-15	F	N	F,C,E	C,E
24	6/25	N	N	F,C,PP	N
25	7/05	N	N	F,C	N
26	7/07	N	N	F,E	N
27	7/08 (am)	N	N	F,E	N
28	7/08 (pm)	N	N	F,E	N
29	7/26	N	N	F,E	N
30	7/27	N	N	F,E	N
31	8/07	N	R	F,C	N
32	8/29	F,C	D	N	R
32.5	8/30	F,C	F,C	N	R
33	9/03	F,C	F,E	N	R
34	9/14	F,C	F,C	N	R
35	9/15	F,C	F,C	N	R
36	10/26	F,C	D	N	N
37	10/31	F,C	D	N	N
38	11/08	E,C	F,C	N	N

C - conventional quality data obtained
F - flow data obtained
T - toxic quality data obtained (metals and pesticides mentioned in work plan)
M - metals only quality data obtained (metals mentioned in work plan)
N - station not operational
E - some or all of equipment not operating
O - dam open (no removal due to settling)
D - basin behind dam not full, no outflow from dam
R - insufficient rainfall in this watershed, no runoff
()* - fecal coliform sample only
PP - priority pollutant sample collected

be obtained. The background sampling included water, sediment, and fish tissue sampling from stations in both Town Lake and Lake Austin.

Samples were collected from three stations located in each lake in order to detect the presence of any constituent which may represent a potential environmental hazard. Such sampling should provide data on the relative magnitude of ambient pollutant concentrations in the waters, sediments, and fishes of the two impoundments. Moreover, any long-term accumulation of potentially toxic materials in the sediments and biomass of the lakes should be revealed by these screening processes. Three sediment grabs and three adult fish samples were taken at each of the six field stations for subsequent laboratory analysis. Sediment grab sampling also was conducted at the major tributaries in Town Lake and Lake Austin in order to expand upon available data regarding long-term accumulation of toxics. A list of those parameters which were monitored in the water, sediment, and fish tissue samples taken from the lakes is presented in Table 15.

The majority of the 129 priority toxic pollutants are not included in the constituent list presented in Table 15; however, it does contain those pollutants which have been documented by the ongoing USGS lake quality sampling program. A complete priority pollutant analysis was not included in the receiving water study; nevertheless, priority pollutant sampling of storm water runoff in tributary test watersheds (Northwest Austin and Rollingwood) was used to identify additional pollutants of concern and these data permitted an appropriate update of the analysis list.

The Austin NURP background screening study was necessary in order to assess the current status of available data on the presence of toxic materials in the subject receiving water bodies since only a small number of these hazardous constituents have been found in the water column of the lakes during previous monitoring efforts. (Should high levels of a specific toxic substance be detected in the environment, this would necessitate additional sampling to determine the extent of its spatial and temporal distribution in the receiving water body.) The Austin NURP screening survey emphasized the collection of fish samples in order to determine body burden of the suspect pollutant present in the tissue of different fish species, and to examine the prevailing resident community structure and diversity for signs of pollutant-related stress.

TABLE 15

CONSTITUENT ANALYSES PERFORMED DURING BACKGROUND SAMPLING SURVEY ON LAKES

Parameter	Environmental Media		
	Water	Sediment	Tissue
General			
Specific conductance, in situ	✓		
pH, in situ	✓		
Temperature, in situ	✓		
Dissolved oxygen (DO), in situ	✓		
Sediment volatile fraction		✓	
Sediment particle size distribution		✓	
Light-Intensity-Related			
Transparency (Secchi disk), in situ	✓		
Color	✓		
Organic Pollution			
Five-day biochemical oxygen demand (BOD_5), total	✓		
Fecal coliforms	✓		
Total chemical oxygen demand (COD)	✓		
Total suspended solids (TSS)/turbidity	✓		
Total dissolved solids (TDS)	✓		
Total organic carbon (TOC)	✓		
Nutrients			
Nitrate-nitrogen	✓		
Nitrite-nitrogen	✓		
Ammonia-nitrogen	✓		
Total Kjeldahl-nitrogen (TKN)	✓	✓	
Alkalinity (HCO_3^-, CO_3^-)	✓		
Total phosphorus	✓		
Dissolved orthophosphate	✓		
Metals			
Arsenic	✓	✓	✓
Copper	✓	✓	✓
Lead	✓	✓	✓
Mercury	✓	✓	✓
Zinc	✓	✓	✓
Cadmium	✓	✓	✓
Toxic Organics			
Total hydrocarbons			
Defoliants			
Total 2,4-D (2,4-dichlorophenoxyacetic acid)		✓	
Total 2,4,5-T (2,4,5-trichlorophenoxyacetic acid)		✓	
Total diazinon		✓	
DDD		✓	✓
DDE		✓	✓
DDT		✓	✓
Polychlorinated biphenyls			✓

Samples collected in the sediment deposits located at the mouth of major tributaries were designed to indicate the distribution of toxics in the coarse-grained sediments, while mud samples collected in the deepest portions of the lakes near the dams reflected the slow accumulation of hazardous materials associated with fine-grained sediments. Sediment collection sites were generally limited to those locations where suspicious levels of one or more toxic substances previously have been detected.

The basic purpose of the Austin NURP background screening survey was to provide supplemental information to the existing lake data base for targeting the receiving water study to those areas most likely to be impacted by storm water runoff pollutant contributions. The screening survey sought to verify the observed water quality conditions using a selected (and somewhat expanded) list of constituents and by utilizing new stations located near tributaries where runoff contributions would be the greatest.

While ambient water quality conditions serve to reflect the short-term effects of storm water runoff inputs on the receiving waterbody, the screening survey included the analysis of fish tissue and sediments for potentially toxic and environmentally-persistent compounds as longer-term measures of the impact of runoff pollutants on the lake and its biota. The buildup of potentially toxic compounds could occur in areas of the lake such as tributaries which receive large contributions of runoff-generated pollutants from nonpoint sources and where depositional processes are active. The screening survey attempted to scrutinize those areas because they probably would represent the worst-case condition for impact from runoff-related inputs.

METHODOLOGY

Storm Water Sampling

The storm water sampling program consisted of the following: (1) the initiation and maintenance of storm water runoff monitoring within the test sites; and (2) the collection of flow versus stream depth measurements in order to calibrate the flow measurement equipment.

The USGS maintains a network of 24 recording rain gauges throughout the Austin urban area. These gauges are distributed within various drainage basins in order to measure total precipitation and to define rainfall intensities and durations. In addition to these gauges, the City of Austin maintained a recording rain gauge in each of the test watersheds in order to develop a more accurate estimate of rainfall intensities and durations during the NURP survey. The locations of these rain gauges were presented in Figure 11.

The measurement of discharge at each of the sampling stations was accomplished by means of a flow constriction built for the purpose of causing critical depth to occur within the open channel. This approach utilized the principle of the critical depth meter which has an advantage over a weir in that it does not require a stilling basin and is practically invulnerable to damage by floating debris. The critical depth meter was made by raising a portion of the bottom of selected culverts which were designated as hydraulic controls within the test watersheds. It is known that raising the channel bottom a certain amount causes backwater upstream from the constriction and critical depth in the constriction. Since the exact location where critical depth occurred was difficult to determine, the water stage height was measured at a point located a short distance upstream from the control meter. This depth was related to flow by the use of the appropriate relationship for the particular type of channel cross-section.

It was impossible to measure the actual critical depth of flow in the constriction because its exact location was not known and the water surface was often wavy at that location. For these reasons, the water stage height was measured a short distance upstream from the throat. (It is desirable to locate the point of stage height measurement as near to the throat as possible in order to minimize the energy loss between the stage height recorder and the location of critical depth.)

The depth of flow upstream from the control was measured with either a noncontact liquid level sensor or a nonclogging bubbler level recorder. Since the former flow sensor does not come in contact with tne streamflow, inaccuracies and malfunctions caused by floating debris were totally eliminated.

The critical depth meters at each of the designated hydraulic controls within the test watersheds were calibrated by the independent development of site-specific stage-height-discharge rating curves. Field determination of current velocity at predesignated channel cross-sections allowed computation of instantaneous discharges at various water depths at each sampling location. Current velocity measurements were taken during several sampled storm water runoff events in order to establish as thorough a data base as possible. Current velocity was measured with a current meter at several locations at the channel centerline and at selected horizontal intervals toward the water's edge on both sides of the channel. If the water was less than 2.5 feet deep at the measurement location, the current velocity measurements were obtained at a depth of approximately 0.6 of the total depth, relative to the water surface.

In addition to the aforementioned check on the proposed flow monitoring procedures, the elevation of the highwater mark in the approach channel upstream of the specific culvert used as a control within the test watershed was recorded after each storm event. Specially designed staff gauges were securely installed in the approach channel at each sampling station, and the data obtained from these gauges were used to calculate peak discharge through the culvert by indirect methods.

Storm water samples for chemical and biological analysis were collected with automatic high-speed sequential samplers which maintain a typical suction line velocity of over 2.5 feet per second during normal operation which is acceptable for obtaining representative suspended solids samples. Two of the samplers were constructed of materials which permit the collection of samples for toxic pollutant analysis, and these special samplers were rotated among the various test watersheds throughout the survey period.

Regardless of the method used to obtain the samples, the sampling frequency was established in order to characterize storm water runoff quality during the rising limb, peak, and falling limb of the runoff hydrograph.

Each of the samplers was provided with 24 one-liter polypropylene containers, one of which was filled at each sampling interval. However, the toxic pollutant samplers were provided with smaller volume glass bottles which meet the necessary criterion for collection of selected priority pollutants. The sampling frequency varied among constituents in order to concentrate efforts on those parameters which require more detailed data.

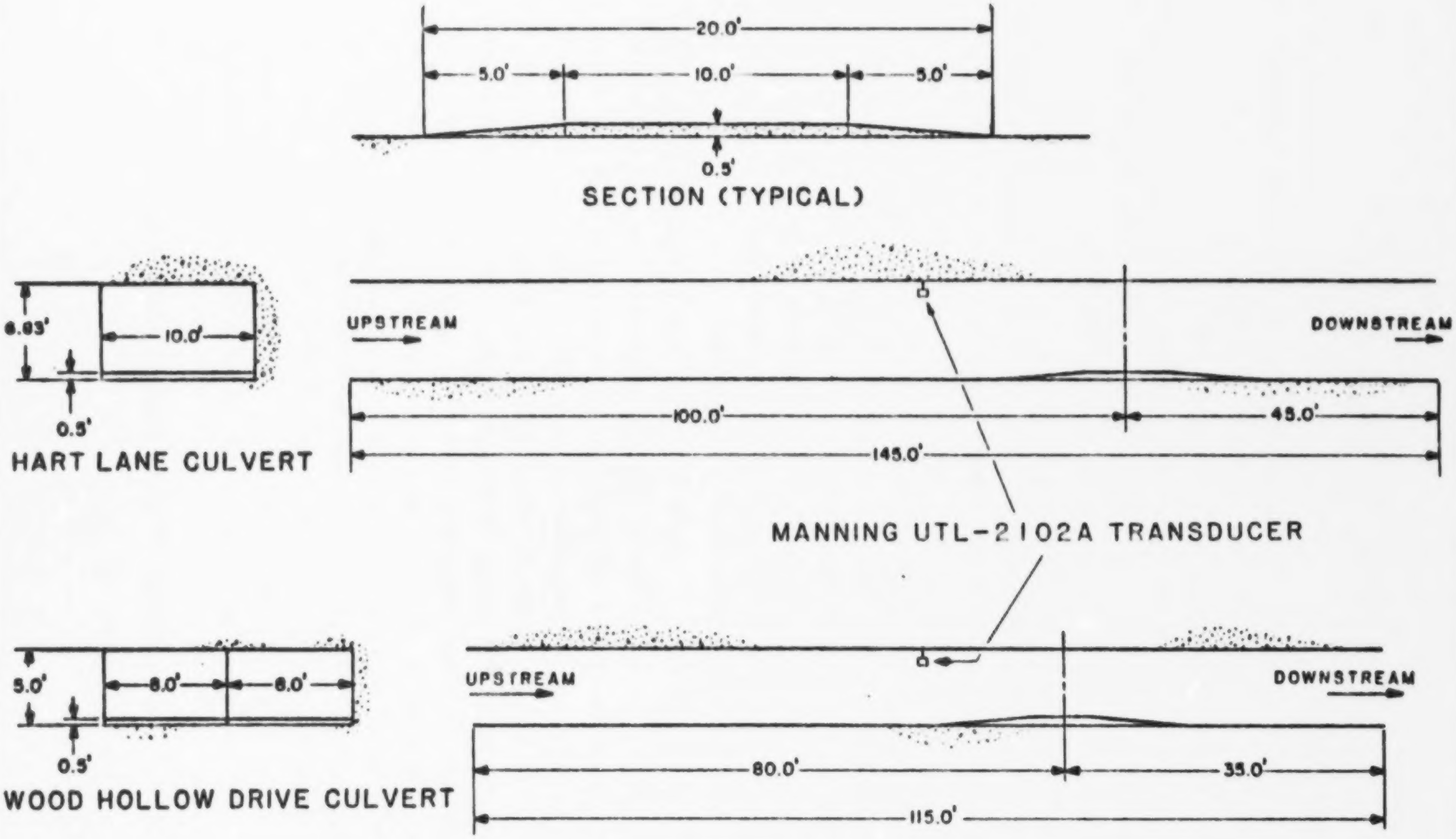
Flow Measurement

In order to calculate the mass loading and/or storm average concentration of pollutants in the runoff from a storm event it was necessary to define both the instantaneous value for the concentration of a given pollutant in the runoff and the total volume of runoff associated with that given pollutant concentration. Laboratory analysis of storm water samples provided information on pollutant concentrations. Total volume discharged was determined from plots of instantaneous discharge versus time. The magnitude of the instantaneous discharge was determined using statistical regression correlations which defined a relationship between water depth and discharge for a given hydraulic control structure. These regression relationships were developed from data generated by hydraulic control structures which were installed at three sites, namely, Rollingwood, Hart Lane, and Woodhollow Dam. These data allowed the storm water runoff discharge to be related directly to depth of flow in the stream channel. The two types of hydraulic control structures used during the study were the critical depth meter (Hart Lane and Woodhollow Dam) and the HL-type flume (Rollingwood).

The critical depth meters used in the Austin NURP study were developed by raising the channel bottom in the box culverts under Hart Lane and Woodhollow Drive. The water depth was measured just upstream of the meter using the Manning UTL-2102A level transmitter and recorder. Figure 19 presents a schematic view of the critical depth meter and measurement equipment. Theoretically, the instantaneous discharge at any time can be calculated given the culvert's slope, dimensions, and water depth. However, since the box culverts used during the study were not ideal for flow measurement, the actual discharge was measured simultaneously with measurements of water depth over a range of depths and flows. The regression relationships between water depth and discharge for the Hart Lane and Woodhollow Drive box culverts are shown in Figure 20 and 21, respectively. During runoff events a continuous record of water depth was provided by the strip chart recorder in the UTL-2102A. From this record a hydrograph was developed for each storm event, and from these data a determination of total discharge volume was made.

The same type of record was obtained at the Rollingwood site, although the hydraulic control used was an HL-type flume rather than a critical depth meter. A flume is a device which causes a flow restriction in an open channel.

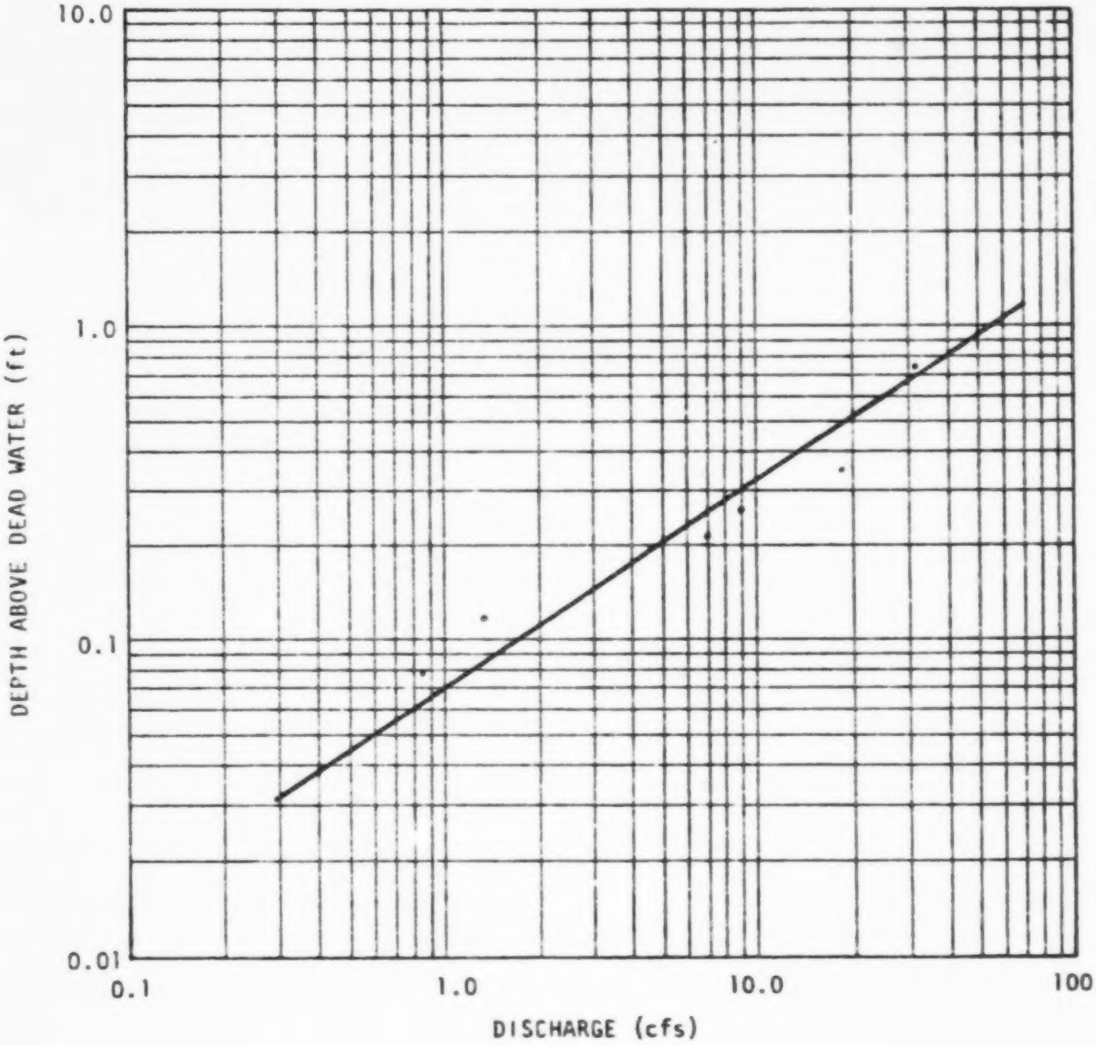
CRITICAL DEPTH METERS


20.0'
5.0'
10.0'
5.0'
0.5'
SECTION (TYPICAL)
6.83'
10.0'
0.5'
HART LANE CULVERT
UPSTREAM
DOWNSTREAM
100.0'
45.0'
145.0'
MANNING UTL-2102A TRANSDUCER
5.0'
6.0'
6.0'
0.5'
WOOD HOLLOW DRIVE CULVERT
UPSTREAM
DOWNSTREAM
80.0'
35.0'
115.0'

NOTE: SECTIONS NOT TO SCALE

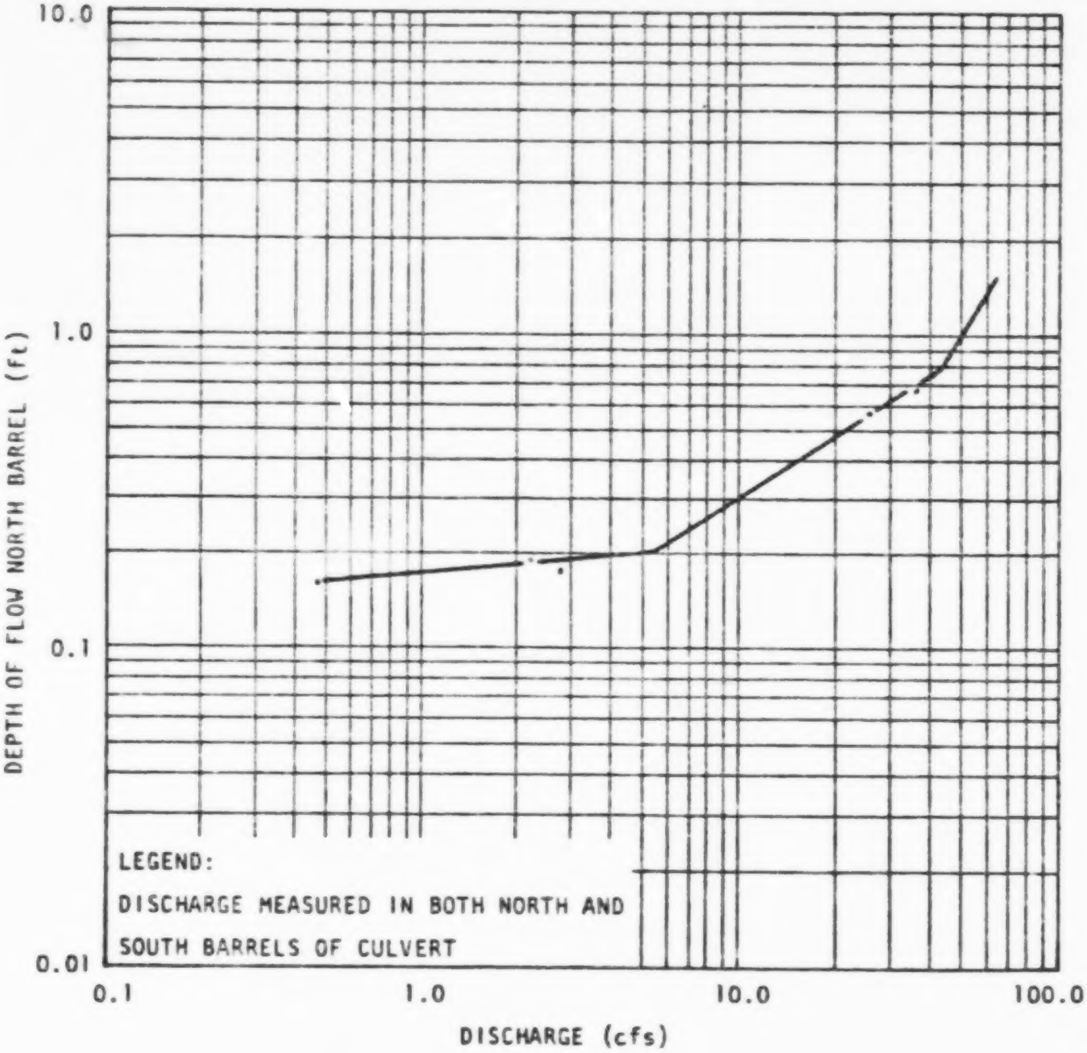
STAGE HEIGHT - DISCHARGE RELATIONSHIP

HART LANE BOX CULVERT



STAGE HEIGHT - DISCHARGE RELATIONSHIP

WOODHOLLOW DRIVE BOX CULVERT



This restriction is such that discharge may be determined by measuring the water depth upstream of the flume. Figure 22 is an isometric representation of an HL-type flume. An important difference between this flume and the critical depth meters used at the Hart Lane and Woodhollow Drive is that the flume has been precalibrated and therefore does not require stream discharge observations to verify the measured flow rate. Table 16 gives the stage height discharge relationship for the HL-type flume used during the Austin NURP study.

The Turkey Creek site did not incorporate a hydraulic control structure for flow measurement during the study. Instead, a known cross-section of the stream channel was used as the point of flow measurement. Stream gauging measurements were made during periods of low flow and a record of water depth was kept to allow a stage height discharge curve to be constructed. Unfortunately, due to equipment problems and the fact that several floods changed the physical configuration of the channel a meaningful stage height discharge relationship was obtained only for the latter part of the study and only over a limited range of stream discharges. Due to the problems in flow measurements it was not possible to calculate the mass loads or storm average concentrations associated with pollutants in storm water runoff from the Turkey Creek watershed. Figure 23 shows the measured stage discharge relationship at the Turkey Creek site for the latter part of the study.

Receiving Water Sampling

The receiving water sampling program consisted of the following: (1) to document the water quality in Lake Austin and Town Lake; and (2) to analyze sediment and fish tissue samples from these lakes in order to assess the long-term impacts.

Water Quality Sampling

Water samples were taken at different depths (one foot from the surface, mid-depth, and one foot from the bottom) with a Kahlisco water sampler in order that the vertical water quality dimensions of the discharge plume from the tributaries could be represented accurately. Water temperature, dissolved oxygen, and conductivity values were measured at different water depths in the lakes with the YSI Model 51B and YSI Model 33 in situ monitoring instrumentation. Water transparency also was determined on site with a Secchi

HL FLUME ISOMETRIC

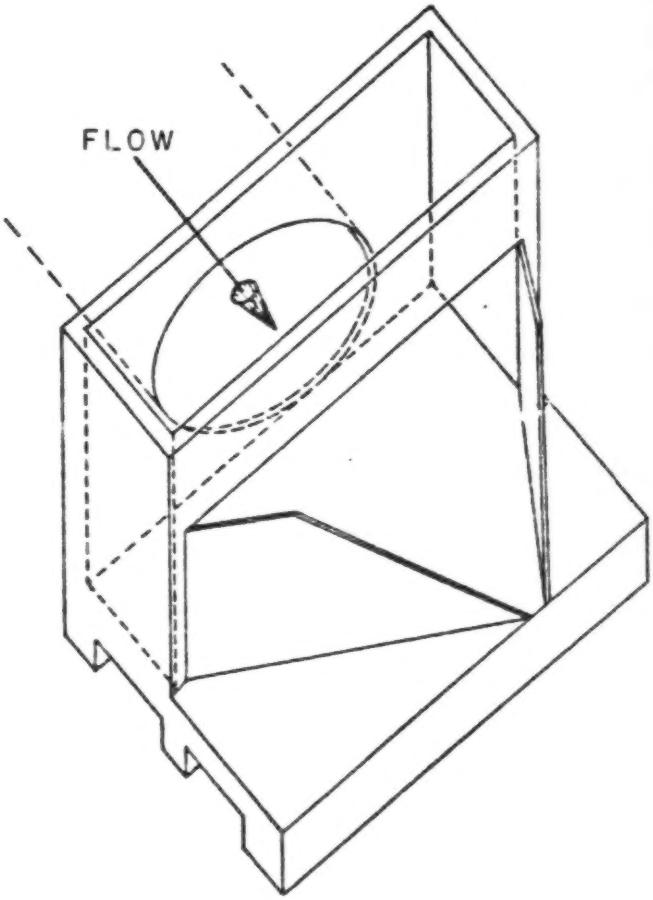


TABLE 16

RATING TABLES FOR 4-FOOT HL FLUME

Head (feet)	Discharge[1] (cfs)									
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0	0	(2)	0.005	0.012	0.020	0.029	0.039	0.050	0.062	0.075
0.1	.089	0.103	.119	.135	.152	.170	.190	.211	.232	.255
0.2	.278	.302	.327	.352	.378	.405	.434	.465	.497	.530
0.3	.565	.600	.635	.670	.705	.740	.780	.820	.860	.900
0.4	.940	.982	1.03	1.08	1.12	1.17	1.22	1.27	1.32	1.37
0.5	1.42	1.48	1.53	1.59	1.64	1.70	1.76	1.82	1.88	1.94
0.6	2.01	2.07	2.14	2.21	2.28	2.35	2.42	2.49	2.56	2.64
0.7	2.71	2.79	2.87	2.95	3.03	3.11	3.19	3.28	3.36	3.44
0.8	3.53	3.61	3.70	3.79	3.88	3.98	4.08	4.18	4.28	4.38
0.9	4.48	4.58	4.68	4.79	4.90	5.01	5.12	5.23	5.34	5.45
1.0	5.56	5.68	5.80	5.92	6.04	6.16	6.28	6.40	6.52	6.64
1.1	6.76	6.89	7.02	7.15	7.28	7.41	7.54	7.67	7.80	7.93
1.2	8.06	8.20	8.35	8.50	8.65	8.80	8.95	9.10	9.25	9.40
1.3	9.55	9.70	9.90	10.1	10.2	10.4	10.5	10.7	10.8	11.0
1.4	11.2	11.4	11.6	11.7	11.9	12.1	12.3	12.4	12.6	12.8
1.5	13.0	13.2	13.3	13.5	13.7	13.9	14.1	14.3	14.5	14.7
1.6	14.9	15.1	15.3	15.5	15.7	15.9	16.2	16.4	16.6	16.8
1.7	17.0	17.2	17.4	17.6	17.8	18.1	18.3	18.5	18.7	19.0
1.8	19.2	19.4	19.7	19.9	20.2	20.4	20.6	20.9	21.2	21.4
1.9	21.7	21.9	22.1	22.4	22.7	23.0	23.2	23.4	23.7	24.0
2.0	24.3	24.5	24.8	25.0	25.3	25.6	25.8	26.1	26.4	26.7
2.1	27.0	27.3	27.6	27.9	28.2	28.5	28.8	29.1	29.4	29.7
2.2	30.0	30.3	30.6	30.9	31.2	31.5	31.9	32.2	32.5	32.8
2.3	33.1	33.5	33.8	34.1	34.5	34.8	35.1	35.4	35.8	36.1
2.4	36.5	36.8	37.1	37.4	37.8	38.2	38.5	38.8	39.1	39.5
2.5	39.9	40.3	40.6	41.0	41.4	41.7	42.1	42.4	42.8	43.2
2.6	43.6	43.9	44.3	44.7	45.1	45.5	45.8	46.2	46.6	47.1
2.7	47.5	47.9	48.2	48.6	49.0	49.4	49.8	50.2	50.7	51.1
2.8	51.6	52.0	52.4	52.8	53.3	53.7	54.1	54.5	54.9	55.4
2.9	55.9	56.3	56.7	57.2	57.6	58.1	58.6	59.1	59.5	59.9
3.0	60.3	60.8	61.3	61.8	62.3	62.8	63.2	63.7	64.1	64.6
3.1	65.1	65.6	66.1	66.6	67.1	67.5	68.0	68.5	69.0	69.5
3.2	70.0	70.5	71.0	71.5	72.0	72.5	73.0	73.5	74.0	74.5
3.3	75.0	75.5	76.0	76.5	77.0	77.6	78.2	78.7	79.3	79.9
3.4	80.5	80.9	81.5	82.0	82.6	83.1	83.6	84.2	84.8	85.3
3.5	85.9	86.5	87.1	87.7	88.3	88.9	89.5	90.1	90.7	91.3
3.6	91.9	92.5	93.1	93.7	94.3	94.9	95.5	96.1	96.7	97.4
3.7	98.0	98.6	99.2	99.8	100	101	102	102	103	104
3.8	104	105	106	106	107	107	108	109	109	110
3.9	111	111	112	113	113	114	115	115	116	116
4.0	117	---------	---------	---------	---------	---------	---------	---------	---------	---------

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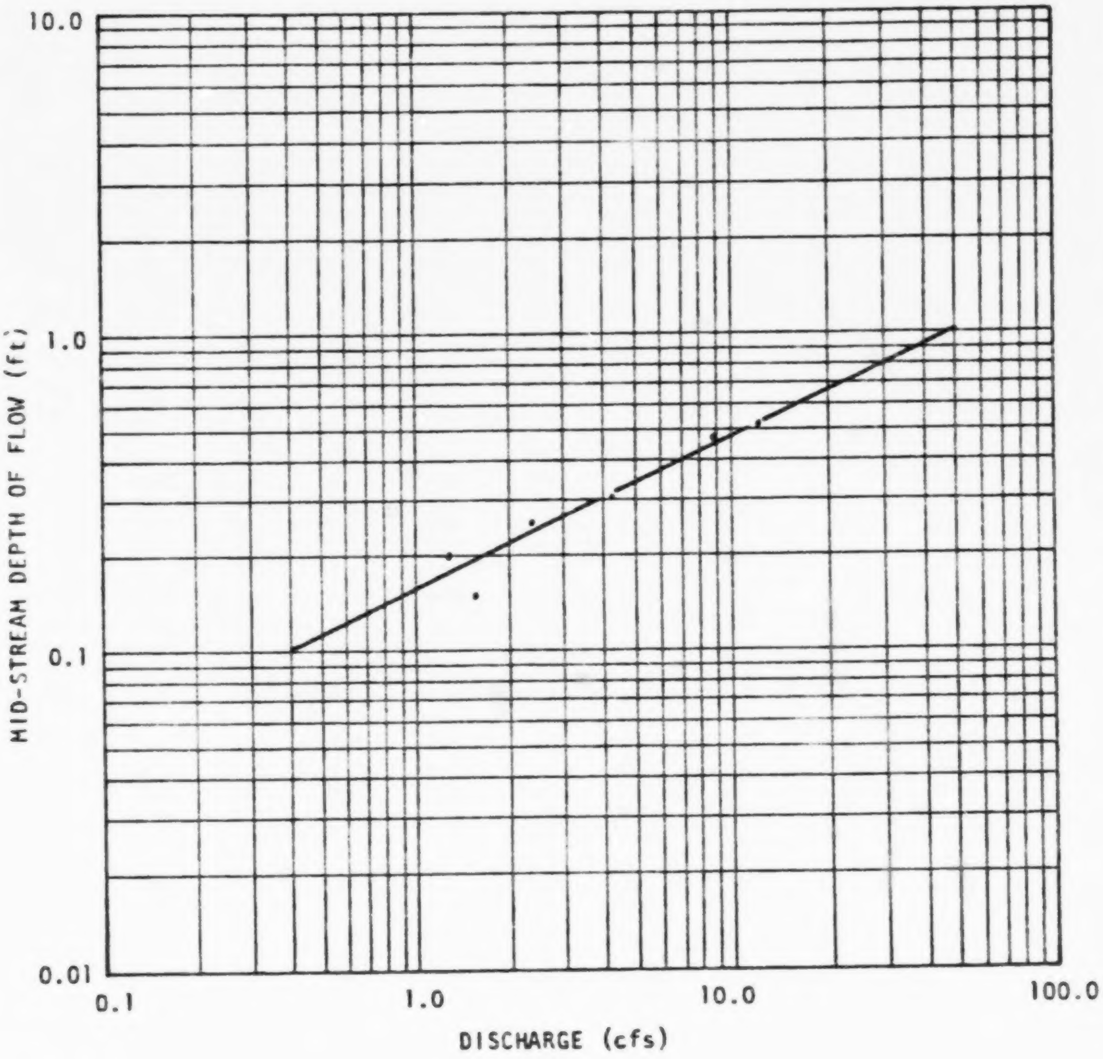
[1] Rating derived from tests made at the National Bureau of Standards using flat floor.

[2] Trace.

STAGE HEIGHT - DISCHARGE RELATIONSHIP

TURKEY CREEK AT CITY PARK ROAD



disc. Water quality stations for the background sampling survey are located as shown in Figures 17 and 18, and the total number of sampling stations for the storm event-oriented water quality surveys also are presented in these figures.

Sediment Quality Sampling

An Ekman Dredge grab sampler was used to collect sediment samples. A total of 23 sediment samples were collected at the six designated background lake sampling stations, namely, ES 1 through ES 6. Sediment grabs were taken at three different points in the same general vicinity to constitute a station. Laboratory analysis included particle size distribution, volatile fraction, total Kjeldahl-nitrogen, heavy metals (arsenic, copper, mercury, lead, zinc, cadmium) and toxic organics (DDE, DDD, DDT, diazinon, 2,4-D, and 2,4,5-T).

Sampling Biological Indicators in the Receiving Water Bodies

The biological sampling program of the Austin NURP study emphasized laboratory analysis of fish tissue in order to identify those toxics which may have bioconcentrated in the lake fishes. This approach utilizes the resident fishes as long-term indicators of chronic exposure to low levels of toxic substances that may have entered the lakes from storm water runoff. These data, when used in conjunction with water and sediment quality data collected during the background sampling effort, provided the basis for a comprehensive ecological evaluation of the impacts associated with storm water pollution.

A minimum of three adult fish were collected alive via hoop net at each of the three stations in Town Lake and the three background stations in Lake Austin. Largemouth bass, redbreasted sunfish, redear sunfish, bluegills, Rio Grande perch, and longnose gars were collected from overnight net sets in both Lake Austin and Town Lake. These fish species were largely predaceous or omnivorous, and no true detritivore or planktivore species were collected.

The fish were analyzed for a select group of organic toxicants and heavy metals that had been detected at various times during prior water quality monitoring activities in the lakes. For instance, DDT and its breakdown products and PCBs comprised the organics test groups, while arsenic, copper, mercury, lead, zinc, and cadmium were the metal parameters of concern.

Bacterial Sampling

Only sterilized bottles with teflon liners were used to collect bacterial samples for total and fecal coliform analysis. Once collected, samples were stored in an iced Igloo cooler and sent to the laboratory within eight hours of the time when the first sample was collected that day. These are essentially the same sampling procedures used for collection of bacterial samples in the storm water runoff monitoring survey.

QUALITY ASSURANCE

A quality assurance program was established for sample gathering and field sampling techniques, sample preservation and handling procedures, equipment calibration and cleaning protocols, and laboratory quality assurance activities. Most of the quality assurance procedures which were followed were taken from standard reference materials including EPA documents, U.S. Geological Survey documents, ASTM standards, etc. Table 17 contains a list of these reference documents. The material contained in these references were applied throughout the sampling and analytical program. Likewise, manufacturer's equipment calibration and cleaning procedures were utilized as appropriate.

The description of the quality assurance program is divided into two major sections, namely, field data collection and laboratory analyses. The field data collection activities include the monitoring of storm water runoff and the implementation of Lake Austin and Town Lake water quality sampling. All field data collection activities were jointly conducted by Engineering-Science (ES) and City of Austin employees. These responsibilities included collection of samples, maintenance of the equipment, and performance of various field measurements, including flow and water quality sampling with field equipment, such as dissolved oxygen analyzers. Laboratory analyses of samples collected during the study, which included both storm water runoff and receiving water samples, were conducted by ES laboratories in Berkeley, California and Auburn, Alabama, and contract laboratories in Austin and Houston, Texas. The breakdown of these laboratory analyses are described in more detail in the section concerning the laboratory quality assurance program. The quality assurance program for the laboratory work included the normal quality assurance programs operated by each of the contract laboratories and, in addition, were subject to the overall quality assurance program for the Austin NURP Study.

FIELD DATA COLLECTION

Collection of data in the field for the Austin NURP Study involved two completely different types of sample sites, namely, storm water and receiving water body stations. Storm water runoff stations were specifically located to

TABLE 17

AUSTIN NURP STUDY
QUALITY ASSURANCE PROGRAM REFERENCE DOCUMENTS

1. Data Collection Quality Assurance for the Nationwide Urban Runoff Program, Water Planning Division, EPA, Washington, D.C.
2. 40CFR136, Guidelines Establishing Test Procedures for the Analysis of Pollutants; Proposed Regulations, 44FR69464-69574, Dec. 3, 1979, and Corrections 44FR75028-75052, Dec. 18, 1979.
3. Methods for the Chemical Analysis of Water and Wastes, EPA, 1979.
4. Standard Methods for the Examination of Water and Wastewater, APHA, 15th Edition.
5. Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents, EPA, 1973, or latest edition.
6. Water Measurement Manual, U.S. Department of the Interior; Bureau of Reclamation, 1967.
7. Stevens Water Resources Data Book.
8. Handbook for Analytical Quality Control in Water Wastewater Laboratories, EPA-600/4-79-019, EPA, 1979.
9. Sampling and Analysis Procedures for Screening of Industrial Effluents for Priority Pollutants, EPA, 1977.
10. Manual of Analytical Procedures for the Analysis of Pesticide Residues in Human and Environmental Samples, EPA, 1979.
11. 1980 Annual Book of ASTM Standards, Part 31-Water.
12. Microbiological Methods for Monitoring the Environment, Water and Waste, EPA, December 1978.

define characteristics of residential land use storm runoff and represent stations where streamflow normally does not exist except during periods of rainfall. These stations were sampled on an intermittent basis related to specific rainfall/runoff events. The receiving water body stations were monitored on both a fixed and intermittent schedule and were intended to provide information regarding the relative impacts of storm water runoff on the water quality and aquatic biology of Lake Austin and Town Lake.

Specific quality assurance samples were collected to supplement the number of samples estimated to be required to meet the objectives of the project. The details of the location of the sampling stations for each type of site and the associated sampling procedures were provided earlier in this report. The quality assurance program described below is divided into two sections, one for each type of sampling location.

Storm Water Runoff Sites

At each storm water runoff station, two types of field data were collected, namely, (1) flow measurements taken during the period of time when runoff was occurring, and (2) water quality samples collected at fixed time intervals during a runoff event so that the temporal variation in runoff water quality as well as the total mass of pollutants from a defined area after a particular rainfall event could be determined. The quality assurance for each type of sample collection activity is described below.

Flow Measurements

At each storm water runoff site, there was a streamflow measuring device consisting of an automatic water stage level recorder which switches on at the beginning of streamflow, a control device such as a flume or channel modification which was used to estabish a defined streamflow condition as described earlier in the report, and, finally, a defined stream section, that was used to develop stage height discharge relationships for measurements of flow under selected conditions. Each of the flow measurement stations was visited several times per week by an ES and/or City of Austin employee to conduct a routine check of the monitoring equipment. These routine checks of the flow measurement equipment include the following: (1) a check of the in-stream flow device for proper operation and calibration with the stage level recorder; (2) a check of the recorder and battery for proper operation; and

(3) a check of the flow control device to be sure it is not obstructed or damaged. After checking the operation of a flow measurement device, an appropriate entry was made in the storm water runoff sampling station log book indicating the date, time, and the results of the checks that were conducted on the flow measuring equipment. A separate log book was used at each storm water runoff monitoring site to record all information collected at that station, including maintenance and calibration records on the equipment, as well as information taken during a sampling event.

At the end of each runoff event, the field team removed the used strip chart from a given recorder and replaced it with a new chart. The date and time of removal was recorded on the strip chart showing the runoff event. The installation date and time for the new chart also was recorded thereon when it was placed in the flow recorder. The routine checks of the flow measuring devices described above were again conducted to assure that the equipment was operating correctly after a runoff event had been monitored.

In addition to the check and maintenance described herein, once every three months each flow measurement station was carefully evaluated to assure that it met the specified design condition. This includes checking the position of the device, the staff gauge position, the condition of the surfaces over which water must flow, etc. The results of these periodic checks of the flow measurement equipment were recorded in the storm water runoff station log.

As a check on the flow measuring capabilities of the continuous monitoring stations, stage-discharge relationships were developed at each storm water runoff station at a location either upstream or downstream of the continuous flow measuring device. During selected runoff events, flow measurements are taken at these defined cross-sections for comparison with the flow measurements taken at the continuous station. Current velocities were measured using a Price AA current meter. These measurements were taken as described in the flow measurement references that were used as the basis for the quality assurance program used by this study. The current meters used were calibrated at the beginning of the study. After each use, the current meters were checked for damage, cleaned, and lubricated. If there was any reason to believe that a current meter had been damaged or may need recalibration, the meter was sent to the appropriate laboratory for maintenance and calibration. The current meters were recalibrated at the end of the study.

Storm Water Runoff Quality Data

As described earlier, automatic samplers were used at each of the storm water runoff stations to collect sequential water quality samples during each runoff event. Each of these automatic samplers were checked weekly by ES/City of Austin personnel to assure that it was in proper operating condition. This equipment check included the following: (1) a check of proper operation of the primer and pump; (2) a check of the battery charge; (3) a check to insure that the flow pick-up in the stream bed was clear of obstructions, (4) that the bottles in the automatic sampler were clean, and (5) that the sampler was properly secured and undamaged. The results of each weekly inspection were recorded in the storm water runoff station log.

At the end of each storm runoff event, a field team visited the station to remove the collected samples, clean up the automatic sampling equipment, and set it up for the next sampling event. The collected samples were removed from the automatic sampler and immediately preserved in accordance with the requirements of the specific analytical tests performed on the sample, as specified in 40 CFR 136 and the EPA Methods for the Chemical Analysis of Water and Wastes, 1979 Edition. These collected samples were immediately sent to the respective laboratories. The automatic sampler was cleaned following the manufacturer's instructions and EPA guidance. New sample bottles were placed in the sampling device, which then was set up to begin sampling at the onset of the next runoff event. Since new sample bottles were used for each runoff event, no cleaning of sample bottles was necessary.

As described earlier in this report, sequential samples were collected during each runoff event in order to define the temporal variation in storm water runoff quality. The automatic samplers used in the study did not provide sufficient volumes of samples to allow splitting of a sample to form duplicates for the quality assurance program. Thus, quality assurance sampling was performed by the field crew by collecting grab samples of storm water runoff coincident with the period during which the automatic sampler was collecting runoff samples. It is recognized that the samples collected by grab and the automatic sampler are not directly comparable. Therefore, the grab sample itself was split and analyzed in duplicate. This was accomplished by the field teams on a random basis throughout the study period. (This also was done with flow weighted composites collected at the various storm water runoff sites.) Approximately 10 percent of the total number of storm water runoff samples collected were matched with these duplicate grab samples by the end of the study. The only chemical sample preservatives required during this study were sulfuric acid and nitric acid; these liquid chemical sample preservatives were prepared fresh from concentrated acids prior to collecting storm water runoff samples and receiving water samples; thus sample preservative blanks did not need to be analyzed.

Each sample was identified by affixing a pressure-sensitive label to the sample container. The identification tags included the following information: (1) unique sample number; (2) date and time sample was collected; (3) description of the sample including the sample station number and the sample type; (4) the preservative used; (5) the analyses required; (6) the name of the collector; and (7) any pertinent field data collected at the same time as the sample. The same information was recorded in the storm water runoff station log book at the time the sample was collected. The sample container was then placed in a transportation case along with a chain of custody record form. As the samples were transferred by the field team to the laboratory, custody transfer was recorded in the chain of custody record. The chain of custody record form used was that specified by EPA in the "Data Collection and Quality Assurance for the Nationwide Urban Runoff Quality Program" guidance document.

Receiving Water Sites

Ten stations were selected in the Lake Austin receiving water body and five stations on Town Lake. At each of these stations, samples were collected to determine receiving water quality, sediment quality, and the level of pollutants in fish from the lakes. The following subsections describe the quality assurance techniques used during the collection of the field data for each of these three major areas. The quality assurance guidance documents identified in Table 17 are the basic reference for all field data collection for the receiving water bodies.

Water Quality

The water quality sampling procedures and the receiving water stations were discussed earlier. The field monitoring equipment used for the receiving water quality surveys were calibrated at the Austin Office of ES before the initiation of a field survey according to the manufacturer's instructions for each specific item of equipment. In addition, for the temperature-dissolved oxygen and conductivity meters, standard solutions were carried by the field teams during the surveys and the instruments were checked for calibration at least once during the course of each survey. Finally, the instrument's calibration was checked at the completion of each survey.

Sediment Samples

Sediment quality samples were collected by dredging. There were no specific sample collection or analysis quality assurance steps that could be implemented for this phase of the receiving water sampling effort other than the collection of multiple samples at a given site. Sediment samples were labeled with the same type of information as the storm water runoff samples. These sediment samples were refrigerated to 4°C for preservation. Chain of custody procedures were the same as those described above for storm water runoff and receiving water quality samples.

Tissue Analysis

Collection techniques for the fish sampling were based on established aquatic biota survey techniques, nevertheless, there were no specific quality assurance steps that could be implemented for this phase of the receiving water sampling effort. Between two and three adult fishes from each sampling site were taken for laboratory tissue analysis. All organisms were placed on ice in the field and then frozen prior to air shipment to the laboratory.

LABORATORY QUALITY CONTROL

Two types of laboratory analyses were conducted as part of the Austin NURP Study, namely, chemical analyses and biological analyses. The quality assurance programs for each of these types of laboratory analyses are described below. All quality assurance, whether for chemical analyses or biological analyses, were conducted in accordance with the quality assurance program reference documents listed in Table 17. Engineering-Science detection limits for all laboratory analyses are shown in Table 18.

Chemical Analyses

The chemical laboratory analyses which were conducted in support of the Austin NURP Study were performed by several laboratories. The analytical schedule and the laboratories that were responsible are described below:

(1) ES Laboratory, Berkeley, California - This laboratory conducted the analyses for heavy metals, pesticides, and hydrocarbons in all runoff, receiving water, and sediment samples. All of these samples were properly preserved, shipped, and analyzed at the Berkeley laboratory within the time frame required for holding prior to analysis as specified in 40 CFR 136.

(2) Subcontract Laboratory in Austin, Texas - Aqualab, Inc. This laboratory was used to analyze the receiving water quality and storm water quality runoff samples for all pollutants which required measurement within a finite time period of sample collection.

(3) Harmon Engineering and Testing, Auburn, Alabama - This laboratory conducted the analyses for heavy metals and chlorinated hydrocarbons in the fish tissue samples. Fish samples were frozen, shipped, and analyzed at the laboratory as specified in 40 CRF 136.

(4) Subcontract Laboratory in Houston, Texas - Spectrix Corporation - This laboratory conducted the priority pollutant analyses of the Austin NURP storm water runoff samples. All samples, duplicates, and spikes were analyzed for the 13 EPA priority pollutant metals and 114 organic priority pollutants. (Asbestos, total phenols, and total cyanide analyses were conducted by Aqualab, Inc.) The organic priority pollutants were analyzed according to EPA methods 624 and 625 (Federal Register, December 3, 1979, pp 69532-69554). Metals analyses were performed according to Methods of Chemical Analysis of Water and Wastes (EPA 600/4-79-020).

(5) Subcontract Laboratory in Seguin, Texas - Guadalupe-Blanco River Authority Laboratory - This laboratory conducted quality assurance

TABLE 18

ENGINEERING-SCIENCE DETECTION LIMITS FOR ANALYTICAL WORK DURING THE NURP STUDY*

	Sample Type		
	Water**	Sediment	Tissue
Toxic Organics			
Pesticides			
DDD	NA	5	3
DDE	NA	5	2
DDT	NA	5	10
Herbicides			
Diazinon	NA	100	NA
2,4-D	NA	100	NA
2,4,5-T	NA	100	NA
PCB	NA	100	100
Metals			
As	2***	10	20
Cu	1***	10	50
Hg	0.5	2	20
Pb	1***	10	50
Zn	5.0	1	20
Cd	1	1	0.5

NOTE: NA - not applicable.

*All units in µg/l (ppb).

**Receiving water only; for storm water runoff, see Table 36.

***Arsenic, copper and lead were originally taken as 20, 20, and 50 ppb respectively during the early phases of the receiving water study.

analyses on a designated number of samples collected from the storm water monitoring stations during the Austin NURP study.

The approximate breakdown of these quality assurance analyses was as follows: baseline capabilities, one percent; blind duplicate samples, five percent; blind reference standards, two percent; known reference standards, one percent; and spiked samples, one percent. In order to establish the baseline capabilities of each laboratory, double blind reference standards were provided to the laboratory for the numerous water quality parameters measured during this study. The majority of these reference standards were provided by EPA's analytical quality control laboratory in Cincinnati, Ohio. Other standards were prepared by ES. Five replicate analyses of each standard sample were performed by the subcontract laboratory to establish baseline capabilities.

To insure that analytical interferences were minimized, periodic samples were analyzed using the method of additions. In this procedure, the sample was analyzed and then a known quantity of the parameter in question was added (spiked) to the sample which was then reanalyzed. If the difference between the raw sample and the spiked sample differed from the quantity of spike added by more than the percent deviation established in the baseline, then the test was considered out of control and the QACC was notified to determine the cause of the interference and take corrective action to minimize the effect of the interfering substances. Quality assurance data for water quality analyses conducted by Aqualab, Inc. and the Guadalupe-Blanco River Authority Laboratory are shown in Table 19. These data are for conventional pollutants monitored during the Austin NURP study. The quality assurance data for the analysis of metals present in storm water runoff samples are presented in Table 20.

TABLE 19

QUALITY ASSURANCE DATA SUMMARY CONVENTIONAL POLLUTANTS[a]

Sample Number	Sample Type	Pollutant Concentrations						Pollutant Concentrations				
		TOC (mg/l)	COD (mg/l)	NH$_3$-N (mg/l)	TKN (mg/l)	NO$_3$-N (mg/l)	Total P (mg/l)	TSS (mg/l)	TDS (mg/l)	Alkalinity (mg/l)	Acidity (mg/l)	Hardness (mg/l)
R0950[1]	Aqualab QA	-	-	-	-	-	-	-	-	-	-	-
R1304	Aqualab QA	36.0/(36.8)	76./(76.)	1.44/(1.47)	2.53/(2.66)	1.65/(1.67)	.09/(.09)	43./(39.)	123./(122.)	44./(42.)	2./(4.)	80./(80.)
R1403	GBRA Duplicate	20.1/(15.1)	76./(51.6)	2.60/(.02)	2.63/(1.26)	1.62/(4.25)	.24/(.21)	44./(44.8)	213./(142.)	54./(42.5)	2./-	96./(87.3)
R1404	GBRA Duplicate	-	42./(73.9)	2.80/(.16)	3.25/(1.29)	1.64/(3.45)	.29/(.19)	40./(45.8)	185./(115.)	114./(43.)	4./-	92./(81.9)
R1405	GBRA Duplicate	-	38./(53.9)	2.00/(<.01)	2.51/(1.12)	1.12/(2.66)	.17/(.16)	29./(30.4)	86./(130.)	56./(38.)	6./-	72./(65.8)
R1406	GBRA Duplicate	-	228./(54.6)	2.60/(.06)	2.90/(.71)	1.43/(2.08)	.17/(.19)	44./(30.3)	83./(107.)	50./(38.)	8./-	72./(91.8)
R1407	GBRA Duplicate	18.7/(12.4)	76./(67.2)	2.36/(.06)	2.53/(1.05)	1.38/(3.01)	.17/(.18)	64./(82.9)	175./(113.)	48./(41.)	6./-	112./(88.3)
H0109	Aqualab QA	6.4/(6.0)	8./(8.)	.47/(.45)	.98/(1.01)	.61/(.59)	.04/(.03)	47./(32.)	111./(112.)	-	-	-
H0605/ (H0606)	BD (Aqualab)	11.4/(14.6)	69./(72.)	1.50/(1.40)	1.58/(1.41)	.93/(.97)	.15/(.14)	3./(46.)**	166./(111.)	-	-	-
H0609/ (H0610)	BD (Aqualab)	16.2/(14.8)	69./(53.)	1.01/(.77)	1.93/(2.00)	1.22/(1.22)	.11/(.11)	20./(31.)	199./(158.)	-	-	-
H0611	Aqualab QA	14.1/(-)	50./(47.)	.61/(.65)	1.68/(-)	1.26/(1.23)	.09/(.09)	10./(10.)	164./(146.)	-	-	-
H1611	Aqualab Spike*	-/-	200./(228.)	1.00/(1.53)	-/-	1.00/(1.83)	.50/(.80)	-/-	-/-	-	-	-
H1005	Aqualab QA	23.3/(23.1)	15./(15.)	.95/(.93)	1.07/(1.20)	1.05/(1.00)	.17/(.17)	19./(19.)	190./(157.)	82./(82.)	4./(2.)	100./(96.)
H1004	R.S.***	-	-	-	-	-	-	43./(250.)	-	2./(100.)	-	-
H1005	Aqualab Spike*	10.0/(33.1)	200./(209.)	1.00/(1.90)	3.00/(5.14)	1.00/(2.00)	.50/(.62)	-	-	-	-	-
H1503	Aqualab QA	31.4/(30.6)	76./(80.)	2.50/(2.39)	4.24/(4.21)	2.48/(2.55)	.55/(.54)	570./(555.)	291./(225.)	94./(92.)	2./(2.)	160./(124.)
R1002	R.S.***	40./(46.1)	102./(110.)	2.5/(2.8)	5.0/(2.90)	1.0/(1.12)	.05/(.06)	-/(3.)	112./(106.)	-/(1.)	-/(20.)	-/(32.)
W0206	Aqualab QA	17.7/(17.4)	38./(38.)	1.58/(1.63)	1.58/(1.63)	.53/(.56)	.09/(.09)	300./(307.)	124./(145.)	-	-	-
W0402	Aqualab QA	6.6/(5.7)	30./(30.)	1.42/(1.42)	2.48/(2.51)	.74/(.75)	.11/(.11)	13./(17.)	244./(204.)	-	-	-
W1252	Aqualab QA	9.9/(10.5)	38./(38.)	2.00/(1.98)	-/-	1.42/(1.39)	.35/(.35)	40./(32.)	159./(169.)	72./(76.)	8./(6.)	156./(164.)
W1252	Aqualab Spike*	10.0/(20.4)	200./(228.)	1.00/(2.95)	-/-	.40/(1.88)	.20/(.58)	-	-	-	-	-
W1307	Aqualab QA	12.7/(11.8)	30./(30.)	1.80/(1.79)	3.55/(3.42)	.70/(.76)	.26/(.26)	25./(28.)	180./(175.)	88./(86.)	8./(8.)	124./(120.)
T0015	Aqualab QA	-/-	19./(23.)	.71/(.83)	1.19/(1.21)	.16/(.10)	.01/(.02)	4./(3.)	273./(278.)	214./(212.)	12./(14.0)	176./(180.)
T0015	Aqualab Spike*	-/-	200./(221.)	2.00/(2.9)	-/-	1.00/(1.29)	.05/(.06)	-	-	-	-	-
H1900	Aqualab QA	12.6/(13.1)	95./(88.)	2.11/(2.11)	2.29/(2.35)	1.34/(1.38)	.26/(.31)	58./(54.)	157./(159.)	74./(74.)	10./(10.)	88./(92.)
H1911	Aqualab QA	6.7/(6.2)	15./(19.)	1.23/(1.25)	1.33/(1.32)	2.24/(2.35)	.06/(.09)	8./(6.)	299./(296.)	82./(70.)	16./(16.)	192./(200.)
H1911	Aqualab Spike*	10./(15.9)	200./(202.)	-/-	-/-	-/-	.50/(.56)	-	-	-	-	-
R1807	Aqualab QA	12.6/(12.4)	38./(42.)	1.01/(1.01)	3.49/(3.44)	.65/(.63)	.23/(.22)	126./(126.)	105./(105.)	76./(78.)	6./(6.)	80./(68.)
R1807	Aqualab Spike*	10.0/(22.0)	200./(240.)	1.00/(2.07)	3.00/(6.32)	1.50/(2.26)	.50/(.75)	-	-	-	-	-
R1851[‡]	Aqualab QA	-/-	-/-	-/-	-/-	-/-	-	-	-	-	-	-
R2404	GBRA Duplicate	12.3/(7.90)	32./(16.9)	.87/(.06)	1.25/(.73)	1.38/(.56)	.19/(.16)	18./(28.6)	118./(88.)	-	-	-
R2405	GBRA Duplicate	14.0/(8.06)	64./(22.9)	.90/(.23)	1.15/(.23)	1.35/(.66)	.19/(.15)	21./(18.8)	126./(96.)	-	-	-
R2406	GBRA Duplicate	11.4/(8.02)	36./(26.8)	.79/(.11)	1.16/(.27)	1.41/(.77)	.16/(.17)	20./(13.6)	163./(111.)	-	-	-
R2503	Aqualab QA	19.6/(18.6)	64./(57.)	.04/(.08)	3.69/(3.05)	.04/(.06)	.62/(.57)	268./(262.)	760./(745.)	-	-	-
R2505	GBRA Duplicate	15.0/(5.7)	36./(71.6)	1.33/(.11)	3.99/(.70)	1.75/(.45)	.49/(.54)	475./(597.)	706./(139.)	-	-	-
R2506	GBRA Duplicate	10.8/(5.3)	75./(30.5)	.77/(.44)	1.22/(.70)	1.30/(.70)	.22/(.31)	69./(108.)	139./(122.)	-	-	-
R2507	GBRA Duplicate	10.2/(6.0)	29./(43.3)	.48/(.09)	1.39/(<.10)	1.21/(.66)	.18/(.25)	72./(66.)	112./(167.)	-	-	-
R2560	GBRA Duplicate	10.6/(-)	-/-	3.22/(.11)	5.00/(1.72)	1.93/(.14)	-	-	-	-	-	-
H3210	Aqualab QA	9.2/(9.3)	-/-	-/-	1.63/(1.69)†	-/-	.09/(.09)	7./(8.)	-	-	-	-
T2303	Aqualab QA	13.6/(13.6)	38./(38.)	2.17/(2.19)	2.37/(2.61)	.58/(.58)	.21/(.21)	412./(416.)	229./(223.)	-	-	-
T2365	Aqualab QA	9.2/(9.5)	36./(36.)	.72/(.75)	1.47/(1.38)	.16/(.11)	.03/(.03)	35./(35.)	381./(393.)	228./(234.)	10./(12.)	212./(212.)
T2365	Aqualab Spike*	-/-	200./(214.)	1.00/(1.86)	2.00/(3.41)	1.25/(1.54)	.50/(.54)	-	-	-	-	-
H3503	Aqualab QA	12.3/11.1	-/-	-/-	10.4 /(10.2)†	-/-	.38/.38	238./232.	-	-	-	-
W3506	Aqualab QA	8.7/7.9	-/-	-/-	2.21/(2.23)†	-/-	.16/.16	20./20.	-	-	-	-
W3506	Aqualab Spike*	10.0/17.3	-/-	-/-	2.00/(4.26)†	-/-	.50/.64	-	-	-	-	-

NOTES: QA = quality assurance replicate sample.
BD = blind duplicate.
RS = reference standard.
GBRA = Guadalupe-Blanco River Authority Laboratory.
[a] Quality assurance sample results are in parentheses.

*Spike amount/amount recovered.

**May be due to bad sample splitting technique.

***Amount added/amount recovered.

†Total nitrogen.

[1] Fecal Coliforms 224,000/(200,000) (No./100 ml)

[‡] Fecal Coliforms 3,000/(3,300) (No./100 ml)

TABLE 20

QUALITY ASSURANCE DATA SUMMARY
METALS

Sample Number	Sample Type	Pollutant Concentrations As (mg/l)	 Cd (mg/l)	 Cu (mg/l)	 Pb (mg/l)	 Zn (mg/l)
H0801T	VD*	.04/(<.01)	<.001/(<.005)	.160/(.030)	.890/(.210)	.510/(.160)
H0802T	VD*	(<.03)/(<.01)	<.001/(<.005)	.016/(.040)	.140/(.220)	.057/(.100)
W1201T	VD*	-/-	<.005/(<.005)	.008/(.020)	.180/(.080)	.220/(5.760)
R1203T	VD*	-/-	<.005/(<.005)	.011/(.020)	<.05/(<.04)	.052/(<.010)
R1403T	VD*	-/-	<.005/(.040)	.008/(<.020)	.330/(.260)	.110/(.040)
R1403T	ES Berkeley BD	-/-	<.005/(<.005)	.008/(.019)	.330/(.560)	.110/(.150)
R1501T	VD*	-/-	<.005/(<.005)	.015/(<.20)	.080/(.120)	.067/(<.010)
R1501T	ES Berkeley BD	-/-	<.005/(<.005)	.015/(.008)	.08/(.08)	.067/(.030)
R1501T	ES Berkeley BD**	-/-	<.005/(<.005)	.015/(.008)	.08/(.11)	.067/(.037)
R1501T	ES Berkeley BD**	-/-	<.005/(<.005)	.015/(.011)	.08/(.26)	.067/(.052)
R1501T	ES Berkeley BD**	-/-	<.005/(<.005)	.015/(.008)	.08/(.31)	.067/(.077)
R1501T	ES Berkeley BD**	-/-	<.005/(<.005)	.015/(.015)	.08/(.19)	.067/(.041)
H1502T	VD*	-/-	<.005/(<.005)	.042/(.080)	.270/(.320)	.100/(.080)
H1503T	ES Berkeley BD	-/-	<.005/(<.005)	.008/(.013)	<.05/(.07)	.022/(.010)

NOTES: VD = Versar duplicate.
BD = Blind duplicate.
Quality assurance sample results are in parentheses.

*Versar, Inc. is an EPA contract lab in Alexandria, Virginia.

**Multiple blind duplicates of the same sample.

DATA ANALYSIS

STORM WATER

Survey Results

An overview of the analytical results obtained during the Austin NURP study for all samples of runoff from the three test watersheds is presented in Table 21. The data presented in this table represent instantaneous concentrations for each pollutant measured during sampling at the four storm water monitoring sites and the statistical parameters listed (mean, median, standard deviation) characterize the distribution of concentration values that would be expected if random samples were collected in the test watersheds during the course of a runoff event. The geometric mean (median) value for each group of instantaneous pollutant concentrations was obtained from probability distributions for instantaneous concentration values associated with storm water runoff samples collected during the Austin NURP study and these data are presented in Appendix A to this report.

These data indicate that in most cases the instantaneous concentration values fit a log-normal statistical distribution. In other words, the natural logarithms of the individual data points are represented by a normal distribution. The relative goodness of fit between the arithmetic normal and log normal (geometric) distributions may be estimated by comparing the mean and median values for each pollutant.

If the mean and median values are identical (or nearly so) the data closely approximate a normal distribution. Most of the data presented in Table 21 do not fit a normal distribution. The plots presented in Appendix A depict the raw data in log-probability space. These data closely fit a straight line when plotted in this manner and thus the data may be said to fit a log-normal distribution much more closely than an arithmetic normal distribution. Therefore, when comparing different data sets the parameter of choice for comparison would be the median, rather than the mean of the data sets.

TABLE 21

SUMMARY OF INSTANTANEOUS POLLUTANT CONCENTRATIONS FOUND IN STORM RUNOFF

Parameter	Site*	High	Low	Median	Mean (Arithmetic)	Standard Deviation (Arithmetic)	Data Pts.
Acidity as $CaCO_3$ (mg/l)	H	18.0	<1.	6.6	8.0	4.30	51
	R	20.0	0.1	6.3	7.5	3.86	58
	Tb/Ts	16.0	4.0	10.8	11.3	3.27	24
Alkalinity as $CaCO_3$ (mg/l)	H	234.	38.	85.6	95.6	49.00	51
	R	192.	0.5	62.8	73.4	35.91	58
	Tb/Ts	254.	184.	219.2	219.0	15.55	23
Ammonia (mg/l)	H	5.90	0.09	1.2	1.40	0.89	84
	R	4.00	0.04	1.3	1.52	0.87	84
	Tb	1.61	0.39	0.8	0.86	0.33	23
	Ts	2.46	0.68	1.2	1.37	0.69	9
COD (mg/l)	H	754.	4.	46.1	68.	87.18	84
	W	46.	8.	29.1	31.	10.18	23
	R	458.	8.	61.6	84.	79.10	84
	Tb	38.	4.	13.5	18.	13.45	23
	Ts	152.	23.	44.7	57.	38.66	9
Hardness as $CaCO_3$ (mg/l)	H	308.	60.	124.0	136.	62.09	51
	R	284.	32.	88.2	97.	45.52	58
	Tb/Ts	248.	152.	202.4	204.	31.09	23
Nitrate-N (mg/l)	H	6.10	0.13	1.6	1.95	1.36	84
	W	3.00	0.26	1.0	1.23	0.77	23
	R	14.10	0.21	1.0	1.39	1.81	85
	Tb	0.33	0.07	0.13	0.14	6.54	23
	Ts	0.58	0.11	0.25	0.28	0.16	9
TKN (mg/l)	H	30.00	0.69	2.3	3.19	3.78	97
	W	3.83	1.08	2.3	2.48	0.94	26
	R	7.82	0.10	2.2	2.72	1.76	84
	Tb	1.97	0.75	1.2	1.27	0.32	23
	Ts	3.00	1.00	1.9	1.99	0.62	9
Total P (mg/l)	H	3.40	0.03	0.2	0.31	0.42	104
	W	0.37	0.08	0.2	0.22	0.08	34
	R	3.60	0.04	0.22	0.29	0.39	85
	Tb	0.31	<0.01	0.03	0.04	0.07	21
	Ts	0.24	<0.01	0.06	0.10	0.09	9
TSS (mg/l)	H	1,428.	1.	47.0	127.0	198.5	104
	W	170.	6.	26.3	36.6	35.8	34
	R	1,635.	1.	81.5	187.4	270.8	85
	Tb	9.	1.	2.5	3.4	2.6	24
	Ts	412.	9.	68.7	132.1	148.1	9
TDS (mg/l)	H	640.	83.	210.6	234.	115.52	91
	R	1,670.	13.	151.4	206.	223.11	85
	Tb/Ts	1,054.	226.	311.0	328.	144.67	33
TOC (mg/l)	H	270.0	2.9	13.3	18.9	29.34	90
	W	31.1	5.2	12.4	13.5	5.73	31
	R	446.0	7.2	22.2	32.5	51.69	82
	Tb	23.2	1.4	6.7	8.9	6.92	16
	Ts	51.9	9.2	17.3	19.6	12.82	9
Fecal Coliform (No./100 ml)	H**	47,000.	6.	1,422.	8,400.	12,300.	29
	R	224,000.	4.	706.	14,400.	52,500.	18
	Tb/Ts	1,500.	4.	24.	142.	393.	14

* H = Hart Lane (Northwest Austin)

W = Woodhollow Dam (survey station with 24" pipeline closed)

R = Rollingwood

Tb = Turkey Creek background data

Ts = Turkey Creek storm data

** Includes data collected at Woodhollow Dam survey station.

The parameters for which there appears to be a significant difference in the instantaneous pollutant concentrations between the Northwest Austin and Rollingwood watersheds are: nitrate-N, TOC, COD, TSS, and fecal coliforms. The Rollingwood watershed displays higher median instantaneous concentrations of all these parameters (except fecal coliforms and nitrate-N which are higher at the Northwest Austin site) in storm runoff than does the Northwest Austin watershed although these differences are not considered significant since most of these values are usually only slightly higher at Rollingwood. It appears that these instantaneous pollutant concentrations are characteristic of the two test watersheds and are representative of their landuse patterns. In addition, distinct seasonal variations in the measured instantaneous concentrations of each of the pollutants were observed at both the Hart Lane and Rollingwood sites although because of the small number of samples analyzed from the two sites it was not possible to determine whether these differences are meaningful.

In general, the instantaneous pollutant concentrations found in storm water from the two test watersheds do not differ greatly from the control watershed, although the level of fecal coliforms show marked differences. These data indicate that the instantaneous concentrations of fecal coliform bacteria are significantly higher at the Northwest Austin and Rollingwood sites than at Turkey Creek. The values obtained for fecal coliforms from the two test watersheds are high and appear to be typical of low-to-medium-density residential development in the Austin area. There also is a distinct difference in the magnitude of the median fecal coliform values between the two urbanized watersheds, with the Northwest Austin median value being approximately twice that of the Rollingwood site.

During the course of the Austin NURP study, several random bacteriological sampling surveys and alternate analytical approaches were undertaken in order to assess the significance of the high fecal coliform concentrations encountered in the storm water runoff from the two test watersheds. These alternate analytical and sampling approaches included:

(1) Analysis for total as well as fecal coliforms to confirm the presence of high concentrations of bacteria in Austin area storm water runoff;

(2) Sampling upstream of the Hart Lane monitoring station at the Northwest Austin site to determine if a sanitary sewer leak existed which might be responsible for the high fecal coliform concentrations in the storm water from this watershed; and

(3) Sampling in a number of different watersheds in the Austin area during the same runoff event in order to determine if high fecal coliform concentrations were typical of storm water runoff from Austin residential areas in the western half of the city; and

The first analytical screening surveys confirmed that the high fecal coliform concentrations measured in Austin storm water were, in fact, substantiated by the presence of high levels of background coliforms as measured by standard membrane filter procedures. All high values for fecal coliforms present in storm water samples were accompanied by correspondingly high values for total coliforms, indicating that the fecal values were at a representative level given the magnitude of the total coliform population. The second set of analytical screening surveys indicated that the fecal coliform values detected upstream of the Hart Lane monitoring site were not abnormally high relative to the bacteria concentrations measured at this Austin NURP survey station. The storm water samples collected displayed similar concentrations of fecal coliforms indicating that the possible discharge of raw sewage in the upsteam subwatersheds probably was not a cause for the high bacteria counts. A set of random storm water samples collected on June 16, 1981 yielded the results presented in Table 22. All samples were collected on the same day and thus depict the relative level of fecal coliforms present at different locations in the City. These data seem to indicate a widespread presence of relatively high levels of fecal coliform bacteria in samples that were collected in watersheds other than those monitored by the Austin NURP study.

The storm water quality from the control watershed (Turkey Creek) was compared to that from the two test watersheds (Northwest Austin and Rollingwood) in order to assess the relative level of water quality impact associated with residential development in Austin. Generally, the Turkey

TABLE 22

RANDOM BACTERIOLOGICAL SAMPLING SURVEY DATA

Watershed	Sampling Location	Time of Collection* (hours)	Fecal Coliforms (No./100 ml)
Shoal Creek	On Shoal Creek in 4900 block of Shoal Creek Blvd.	1050	2,700
Bull Creek	At Bull Creek Park	1125	2,900
Barton Creek	1/4 mile upstream of Barton Springs	1330	1,650
Northwest Austin (NURP)	Hart Lane monitoring station	1105	210
	Hart Lane monitoring station	1430	6
Rollingwood (NURP)	Rollingwood monitoring station	1340	460
Turkey Creek (NURP)	Turkey Creek monitoring station	1140	100

*Survey conducted June 16, 1981.

Creek watershed displayed lower concentrations of the nutrients and oxygen demand causing substances in storm water runoff than did either of the other test watersheds. Median values for hardness, alkalinity, and TDS are higher at Turkey Creek due to the fact that runoff at this site has been in contact with the characteristic calcium carbonate substrate (limestone) in the watershed for a much longer period than runoff in the other two watersheds. The data presented in Table 23 depict a statistical comparison between the medians of the instantaneous concentrations of several pollutants for both background and storm event conditions at the Turkey Creek site. As was expected, the medians of the storm event data were significantly higher than data for the baseline condition.

A comparison between the medians of the instantaneous pollutant concentrations measured in storm water runoff from the Northwest Austin, Rollingwood, and Turkey Creek sites is presented in Table 24. These data indicate that the median value for the instantaneous pollutant concentrations in storm water collected at the Rollingwood site is generally higher than Northwest Austin for such parameters as COD, TOC, and TSS. However, these values are similar in magnitude for the two test watersheds for such pollutants as TKN and total phosphorus. The median value for the instantaneous concentrations of fecal coliforms in Northwest Austin storm water samples was greater than that found in storm water samples from Rollingwood.

The overall statistical evaluation of data collected during storm water monitoring in the three test watersheds (Northwest Austin, Rollingwood, and Turkey Creek) was supplemented by a comprehensive set of data analyses which developed hydrographs (Appendix B), pollutant mass flux and cumulative pollutant mass loads (Appendix C), and storm-average concentrations (Appendix D) for each pollutant measured during the Austin NURP study. Multiple variate regression analyses were performed in arithmetic and logarithmic space to determine practical correlations between the calculated storm-average concentrations and pollutant mass loadings and such observed storm event data as dry days since last rainfall, duration of rainfall, rainfall volume, runoff volume, average rainfall intensity, and peak rainfall intensity.

TABLE 23

COMPARISON BETWEEN BACKGROUND AND STORM EVENT CONDITIONS AT TURKEY CREEK

Parameter	Median Values of Data Set*		Variance (σ^2)**	
	Background	Storm	Background	Storm
COD, mg/l	13.5	44.7	180.9	1,495
TOC, mg/l	6.7	17.3	47.9	164.4
TSS, mg/l	2.5	68.7	6.8	21,934
TKN, mg/l	1.2	1.9	0.1	0.4
Total P, mg/l	0.03	0.06	0.005	0.008

*Instantaneous concentrations.

**The second moment used as a measure of dispersion.

TABLE 24

COMPARISON BETWEEN NORTHWEST AUSTIN; ROLLINGWOOD, AND TURKEY CREEK STORM EVENT DATA

Parameter	Median Values of Data Set*			Variance (σ^2)**		
	Northwest Austin	Rollingwood	Turkey Creek	Northwest Austin	Rollingwood	Turkey Creek
COD, mg/l	46.1	61.6	44.7	7,600	6,257	1,495
TOC, mg/l	13.3	22.2	17.3	861	2,672	164
TSS, mg/l	47	81.5	69	39,402	73,333	21,934
TKN, mg/l	2.3	2.2	1.9	14.3	3.1	0.4
Total P, mg/l	0.2	0.2	0.06	0.2	0.2	0.01
Fecal Coliforms, No./100 ml	1,422	706	24***	151.29×10^6	$2,756.25 \times 10^6$	0.15×10^6

*Instantaneous concentrations.

**The second moment used as a measure of dispersion.

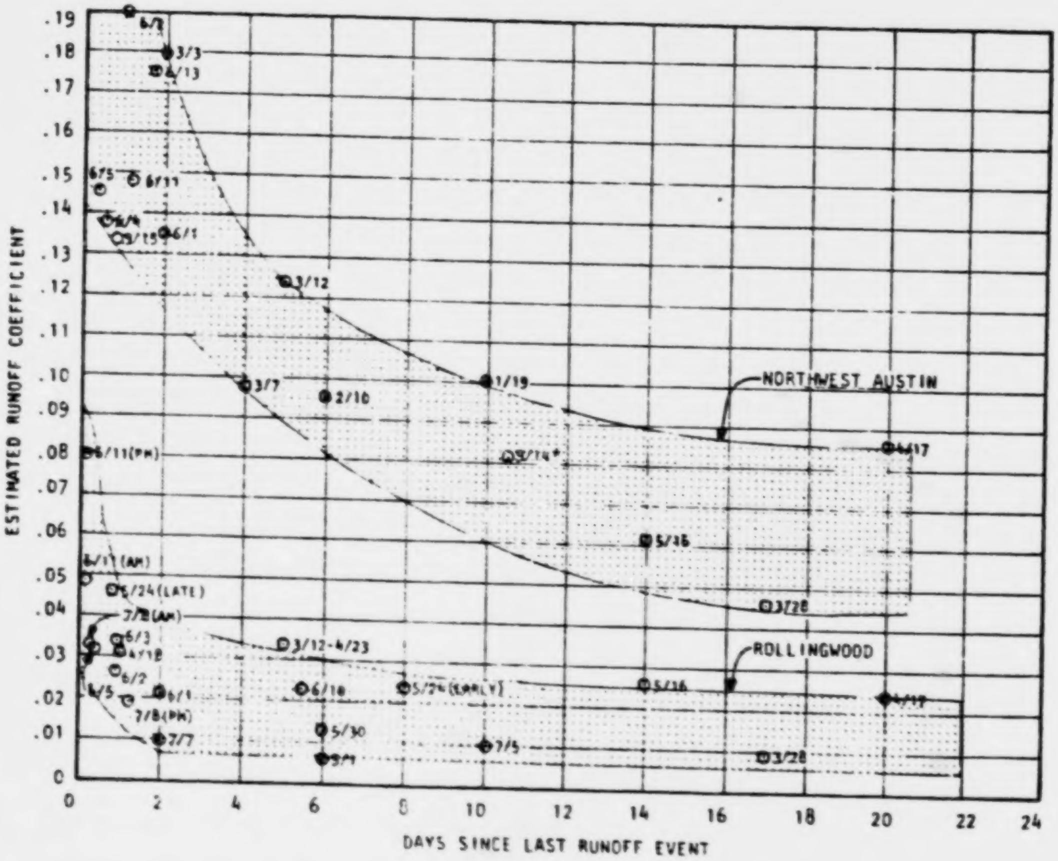
***Includes background data for Turkey Creek (the majority of available data are background since only two storm events were monitored at this site).

A parameter which was measured during the study and which displays a significant difference between the two test watersheds is the estimated runoff coefficient. The runoff coefficient is a measure of the effective abstraction for the area. (That portion of the total precipitation which is considered "excess" will contribute directly to the surface runoff and the remaining parts which do not eventually become surface runoff are called the abstraction. It is not appropriate to define the abstraction as water loss since water cannot be lost in the hydrologic cycle. The abstraction is comprised of evaporation, transpiration, interception by vegetation, infiltration into the soil and temporary retention by depression storage. The effective rainfall is that part of precipitation that contributes entirely to the direct runoff and the difference between total precipitation and the effective rainfall is the effective abstraction.) Figure 24 is a plot of the estimated runoff coefficient (as calculated from rainfall-runoff data collected during the Austin NURP study) versus days since last runoff event for the Northwest Austin and Rollingwood watersheds. The plot indicates that the runoff coefficient for Rollingwood ranges from 15 to 25 percent of that for the Northwest Austin watershed, depending upon the antecedent dry period. This is a significant piece of information since, even though the concentrations of pollutants in the runoff from Rollingwood may be somewhat higher than those from Northwest Austin, the total mass discharged per acre from Rollingwood will be much lower given identical rainfall amounts and antecedent dry periods for both watersheds. Another characteristic of the lower density type development as typified by the Rollingwood site is the attenuation of hydrograph peaks and the reduction in the storm water runoff volumes over other types of developed watersheds. Since the runoff coefficient is a ratio between runoff volume and volume of rainfall for a given event, it is dimensionless and independent of the size of the study watershed. Hence, the data presented in Figure 24 graphically depict the runoff volume from both Rollingwood and the Northwest Austin sites. (The magnitude of the runoff volume from the Rollingwood watershed would be 15 to 25 percent of that from the Northwest Austin site on a per acre basis given identical antecedent dry periods.)

USGS data for water years 1978 and 1979, indicate that the magnitude of the runoff coefficients as measured in the two NURP test watersheds appear to

FIGURE 24

NORTHWEST AUSTIN AND ROLLINGWOOD SITES
ESTIMATED RUNOFF COEFFICIENTS



*NOTE: USED ONLY NURP RAIN GAUGE ON 9/15 AND 9/14 TO CALCULATE RUNOFF COEFFICIENTS BECAUSE USGS GAUGES REPORTED RAINFALL WHICH WAS CONSIDERABLY HIGHER THAN THE MEASURED RUNOFF VOLUMES WOULD HAVE INDICATED FOR THE NORTHWEST AUSTIN SITE.

be close to the magnitude of coefficients calculated by the USGS for Austin watersheds of similar characteristics. (The magnitude of the runoff coefficients for the Shoal Creek watershed were estimated by the USGS to average approximately 0.27, with a range of 0.1 to 0.57.) The values of runoff coefficients as calculated by the USGS were generally higher than those estimated for storm events monitored in the Northwest Austin watershed (a subwatershed in the Shoal Creek watershed), however, this may be explained given the fact that the Northwest Austin watershed is located in a fractured limestone recharge zone while most of Shoal Creek is not. (Much of the rain which fell on the Northwest Austin and Rollingwood watersheds probably entered the Edwards Aquifer recharge zone.)

Pollutant loads from the Northwest Austin site are presented in Table 25. These data include rainfall volume, runoff volume, time to peak, and the interval between storms for each of the measured storm events at the Northwest Austin site. A typical set of pollutographs for the Northwest Austin site are depicted in Figure 25. The corresponding pollutant loads associated with storm water runoff from the Rollingwood site are presented in Table 26 while a typical set of pollutographs are presented in Figure 26. Data for each storm event at both the Northwest Austin and Rollingwood sites are presented in Appendix B, and the pollutant mass loads and cumulative pollutant mass discharged during each measured storm event for these sites are presented in Appendix C to this report. These data were used to develop predictive equations which could be used to describe the water quality associated with the storm runoff from the two candidate residential land use types.

Predictive Equations

The storm water runoff data collected from the Northwest Austin and Rollingwood sites were evaluated using multiple regression analysis with four independent variables as a sequence of straight-line regressions. These regression equations are designed to predict the storm-average concentration of selected pollutants. The independent variables used in these regression analyses were days since the last runoff event, average rainfall intensity, peak rainfall intensity, and duration of rainfall. The predictive equations for storm-average concentrations of TOC, COD, NH_3-N, total phosphorus, and TSS in runoff from both Northwest Austin and Rollingwood are presented in Table 27. (The estimated storm-average concentrations for pollutants

TABLE 25

POLLUTANT LOADS FROM THE NORTHWEST AUSTIN SITE
SAMPLE YEAR 1981

Date	Storm Event	Rainfall Volume (inches)	Runoff Volume (cubic feet)	Runoff Coefficient	Time to Peak (hours)	Days Since Last Runoff Event†	Pollutant Loads							
							TOC (lbs)	COD (lbs)	NH_3 (lbs)	TKN (lbs)	NO_3 (lbs)	Total P (lbs)	TSS (lbs)	TDS (lbs)
1/19	00	1.17	175,145	.109	0.95	10	-	-	-	-	-	-	-	-
2/04	01	0.28	3,520	.009	1.94	13	1.55	3.53	0.13	0.21	0.14	-	9.20	24.49
2/10	02	0.33	42,034	.095	0.45	6	102.36	359.23	4.96	10.23	2.06	0.63	527.21	577.56
3/03	04	2.07	504,414	.178	0.80	2	-	-	-	-	-	-	-	-
3/07	05	0.33	45,128	.096	0.96	4	19.98	95.59	3.41	6.57	4.92	0.54	122.23	1,061.96
3/12	06	0.34	58,724	.125	5.80	5	43.03	194.76	3.15	4.91	3.98	0.41	63.87	540.00
3/28-29	07	0.197	12,904	.046	2.21	17	36.96	77.30	2.57	3.38	1.20	0.71	254.43	169.64
4/17	08	0.47	54,088	.085	0.69	20	-	709.52	9.41	33.01	2.25	3.36	1,127.67	839.79
4/18	09	0.10	610	.005	0.88	1	-	-	-	-	-	-	-	-
4/23	10	0.45	1,426*	.002	0.32	5	-	-	-	-	-	-	-	-
5/16	14	0.94	78,024	.061	0.58	14	-	307.51	10.74	17.45	7.71	1.51	746.35	797.37
5/24 (early)	15	NA	129,307	NC	NA	8	136.55	666.0	10.65	19.12	11.89	3.59	2,191.61	1,340.44
6/01	18	0.04	15,626	.140	6.70	2	7.84	33.09	0.86	1.41	3.27	0.14	81.78	265.37
6/02	19	0.25	65,230	.190	2.67	1	64.69	394.03	6.51	8.15	9.25	1.33	748.22	892.33
6/03	20	0.36	45,230	.111	0.64	1	24.01	136.84	2.54	3.85	4.62	0.49	95.55	539.00
6/04	21	0.70	130,320	.137	0.35	0.83	-	-	-	-	-	-	-	-
6/05	22	0.13	26,595	.145	0.50	0.53	-	-	-	-	-	-	-	-
6/11(1st Part)	23***	4.32	877,373	.148	NA	1	-	-	-	-	-	-	-	-
6/13(2nd Part)	23***	3.04	730,553	.180	NA	1.75	-	-	-	-	-	-	-	-
8/29	32.0	0.257	23,407	.066	0.25	11	22.81	-	-	2.27**	-	0.26	66.75	-
8/30	32.5	0.190	40,503	.355	NA	0.42	22.06	-	-	3.45**	-	0.24	23.38	-
9/14	34	0.30	33,768	.082	0.275	10.67	50.2	-	-	19.49**	-	0.74	479.3	-
9/15	35	0.5	92,580	.135	0.125	0.96	63.0	-	-	29.56**	-	1.47	244.0	-

NOTE: Dash means no runoff quality sample collected.

NA = data not available.

NC = data not calculable.

*Possible equipment malfunction.

**Total nitrogen.

***Short duration storms in succession.

****Fecal coliform data cannot be expressed as a mass parameter.

†Some runoff events were not monitored because of equipment malfunction, therefore this variable is not necessarily the days between the dates shown for each event.

FIGURE 25

TYPICAL POLLUTOGRAPH
NORTHWEST AUSTIN SITE

EVENT 34 9/14/81

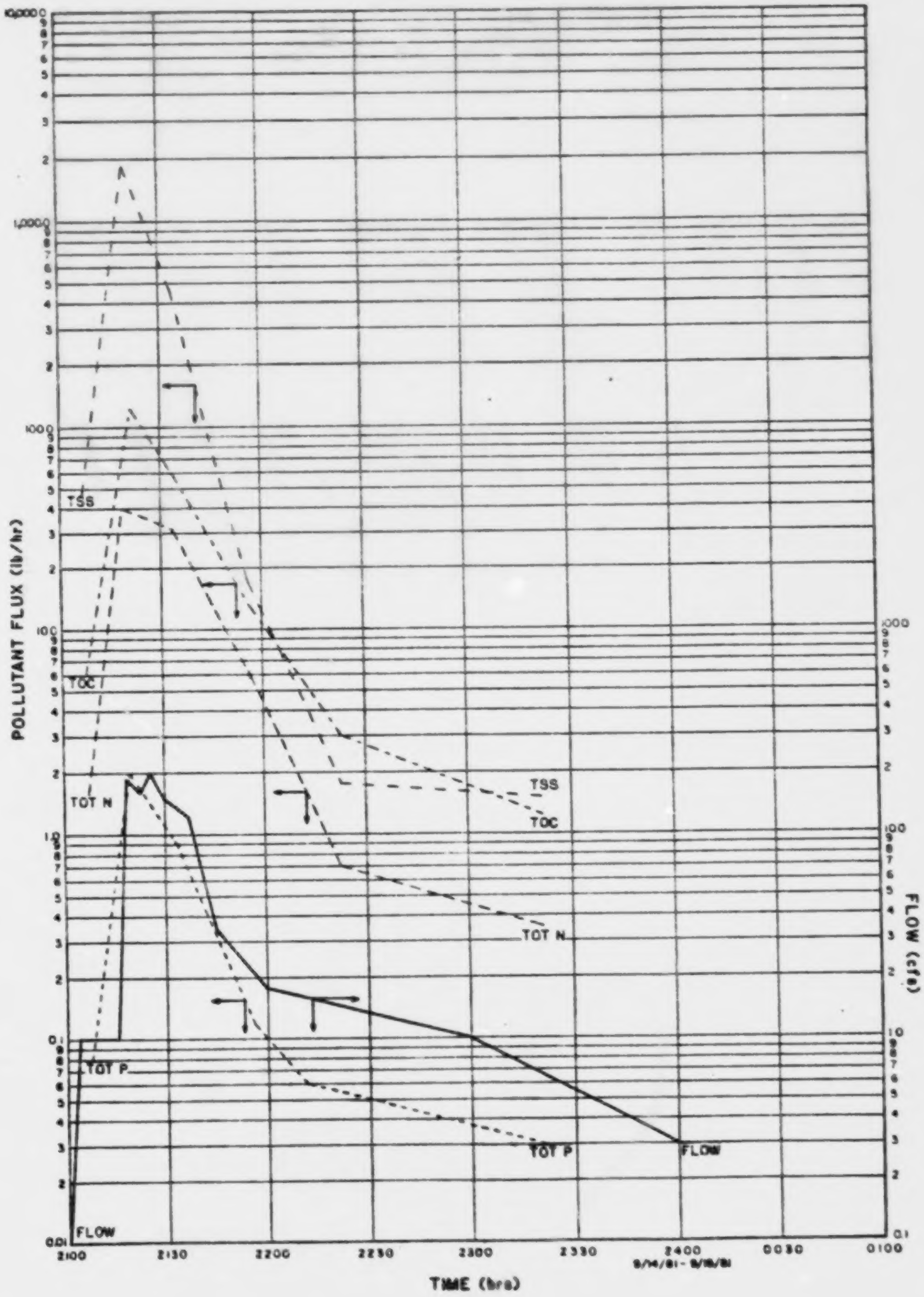


TABLE 26

POLLUTANT LOADS FROM THE ROLLINGWOOD SITE
SAMPLE YEAR 1981

Date	Storm Event	Rainfall Volume (inches)	Runoff Volume (cubic feet)	Runoff Coefficient	Time to Peak (minutes)	Days Since Last Runoff Event†	Pollutant Loads							
							TOC (lbs)	COD (lbs)	NH_3 (lbs)	TKN (lbs)	NO_3 (lbs)	Total P (lbs)	TSS (lbs)	TDS (lbs)
3/12	06	0.213	1,593	.034	16	- 5	-	-	-	-	-	-	-	-
3/28	07	0.26	511.2	.009	7	17	3.99	14.61	0.10	0.10	0.11	0.11	22.55	14.13
4/17	08	0.50	2,573	.024	12	20	10.89	16.40	0.34	0.98	0.14	0.08	69.21	40.20
4/18	09	0.122	771.4	.029	16	1	-	-	-	-	-	-	-	-
4/23	10	0.41	3,001	.034	19	5	-	-	-	-	-	-	-	-
5/01	12	0.98	1,254	.006	23	6	-	-	-	-	-	-	-	-
5/16	14	1.23	6,829	.025	45	14	3.65	35.35	0.44	0.66	0.49	0.08	19.85	57.31
5/24 (am)	15	1.10	5,737	.024	6	8	11.66	47.68	0.62	0.86	0.43	0.17	135.23	129.56
5/24 (pm)	16	4.25	42,559	.046	24	0.771	-	-	-	-	-	-	-	-
5/30	17	1.79	5,027	.013	22.5	6	-	-	-	-	-	-	-	-
6/01	18	0.192	900.5	.021	7.2	2	1.022	3.340	0.046	0.483	0.037	0.015	11.084	7.302
6/02	19	0.459	2,671	.026	22.5	0.79	1.861	5.946	0.218	0.316	0.084	0.028	61.862	22.510
6/03	20	0.260	1,911	.035	5	0.77	-	-	-	-	-	-	-	-
6/04	21	0.223	860.9	.018	8	0.67	-	-	-	-	-	-	-	-
6/05	22	0.35	2,452	.031	45	0.27	1.80	6.01	0.119	0.130	0.047	0.022	5.704	9.056
6/10-6/11 (first part)	23*	1.04	5,174	.023	47	5.5	-	-	-	-	-	-	-	-
6/11 (second part)	23*	3.80	40,814	.049	70	0.042	-	-	-	-	-	-	-	-
6/11 (third part)	23*	3.50	59,968	.078	60	0.021	-	-	-	-	-	-	-	-
6/25	24	1.37	13,784	.046	NA	9	11.828	44.705	0.433	0.681	0.563	0.105	70.540	67.923
7/05	25	1.95	4,248	.010	9	10	4.437	15.001	0.323	0.590	0.285	0.092	47.847	108.035
7/07	26	0.50	996.6	.009	9	2	-	-	-	-	-	-	-	-
7/08 (am)	27	0.21	1,486	.032	21	0.458	-	-	-	-	-	-	-	-
7/08 (pm)	28	0.20	796.1	.018	15	0.646	-	-	-	-	-	-	-	-
7/26	29	0.76	548.4	.003	9	12	-	-	-	-	-	-	-	-
7/27	30	0.20	306.6	.007	19	0.625	-	-	-	-	-	-	-	-
8/07	31	0.45	477.6	.005	30	11	4.33	1.88	0.065	0.176	0.037	0.005	3.892	6.150

NOTES: Dash means no runoff quality sample collected.

NA = data not available.

*Short duration storms in succession.

**Fecal coliform data cannot be expressed as a mass parameter.

†Some runoff events were not monitored because of equipment malfunction, therefore this variable is not necessarily the days between the dates shown for each event.

FIGURE 26

TYPICAL POLLUTOGRAPH
ROLLINGWOOD SITE

EVENT 19 6/2/81

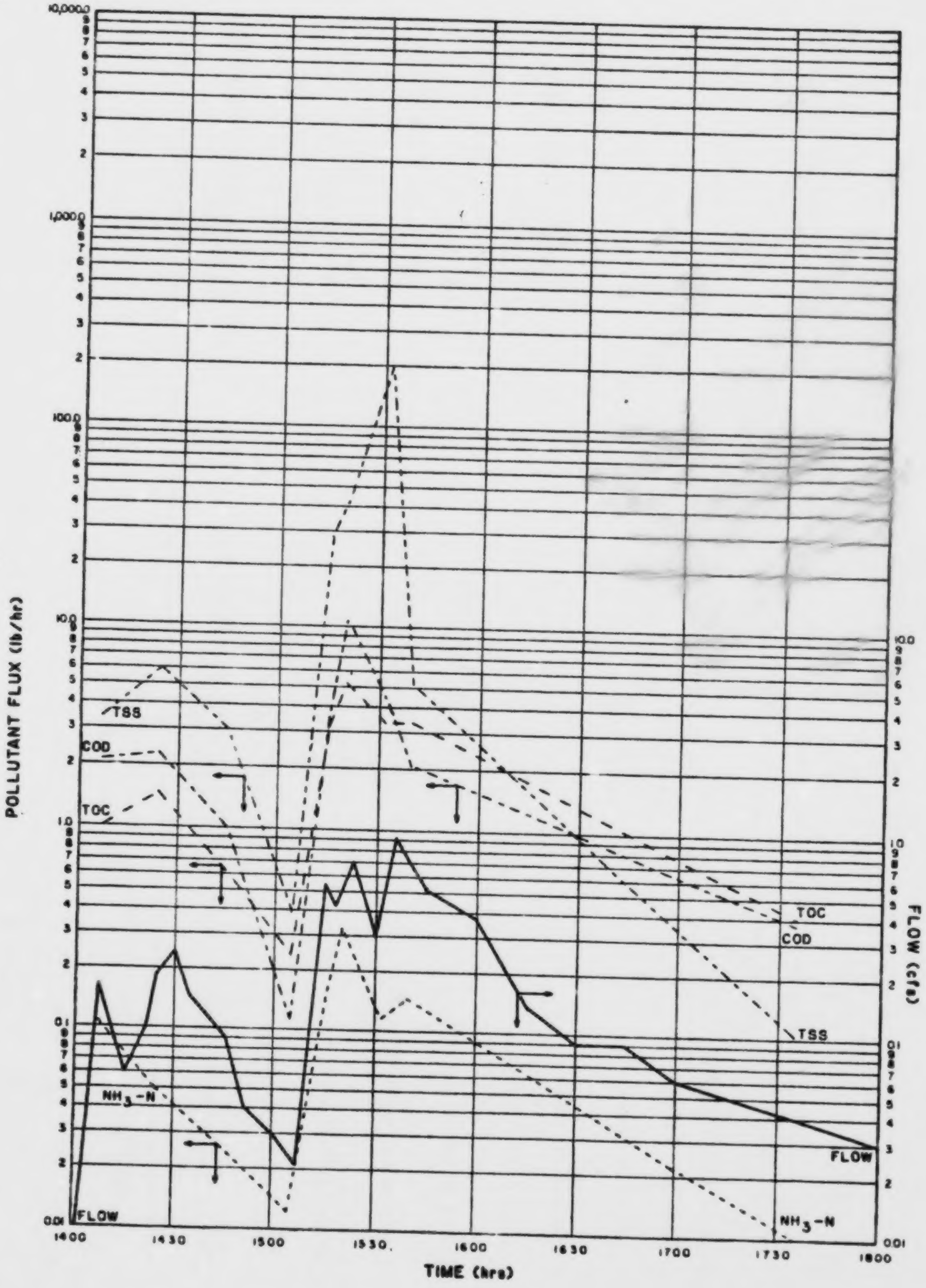


TABLE 27

PREDICTIVE EQUATIONS FOR STORM-AVERAGE CONCENTRATIONS

Parameter	Northwest Austin	Rollingwood
Runoff Coefficient, C		
$T_a \leq 0.5$ in/hr	$C = .1106x^{-.2964}E^{-.2207}$ ($R^2 = .880$)	NA
$T_a > 0.5$ in/hr	$C = .1231x^{-.1982}E^{-.1940}$ ($R^2 = .899$)	NA
$T_p \leq 1.10$ in/hr	NA	$C = .0188x^{-.3178}E^{-.5217}$ ($R^2 = .821$)
$T_p > 1.10$ in/hr	NA	$C = .0096x^{-.2464}E^{-.5988}$ ($R^2 = .622$)
Total Organic Carbon	$S = 4.31 + .39x + 4.85Y + 8.97E$ ($R^2 = .751$)	$S = 1.58x + 4.79Y + 11.32E - 0.29$ ($R^2 = .777$)
Chemical Oxygen Demand	$S = 5.63x + 26.07Y - 0.62$ ($R^2 = 0.727$)	$S = 7.6x + 8.4Y + 47.9E - 1.2$ ($R^2 = .960$)
Ammonia-Nitrogen	$S = 0.11 + 0.14x + 0.55E$ ($R^2 = 0.921$)	$S = .03 + .07x + .13Y + 1.62E$ ($R^2 = .954$)
Total Phosphorus	$S = .03x + .08Y - .02E - .01$ ($R^2 = .881$)	$S = .01x + .02Y + .40E + .01$ ($R^2 = .910$)
Total Suspended Solids	$S = 11.3x + 65.9Y - 62.9E - 1.5$ ($R^2 = .928$)	$S = 17.6 + 3.9x + 23.2Y + 347.5E$ ($R^2 = .766$)

NOTES:
S = storm-average concentration (mg/l).
x = days since last runoff event.
Y = T_p/d (in/hr^2)
E = T_a/T_p
C = runoff coefficient
R^2 = square of the multiple correlation coefficient
T_a = average rainfall intensity (in/hr)
T_p = peak rainfall intensity (in/hr)
d = duration of rainfall (hrs)

measured in storm water runoff from both the Northwest Austin and Rollingwood test watersheds are presented in Appendix D to this report. An example calculation for the determination of pollutant storm-average concentration is presented in Appendix E.) These predictive equations indicate that for several of the pollutants the number of days since the last runoff event is an important variable that affects the storm-average concentration. The interval between runoff events represents an indirect measure of the buildup of pollutants on the surface of the ground (i.e., the larger the number of dry days between storm events, the higher the storm-average concentration of any given pollutant, all other factors being equal). Other variables that also affect the magnitude of the storm-average concentration of various pollutants are rainfall intensity and duration which provides an indirect measure of rainfall volume. These parameters also impact upon the magnitude of the runoff coefficient.

The variables in the regression equations were grouped into the following parameters:

$$E = \frac{T_a}{T_p}$$

where E is a ratio of the average rainfall intensity to the peak rainfall intensity for a given storm event. This parameter is a measure of the overall storm intensity in that values approaching 1.0 signify more uniform rainfall intensities over the course of an event.

And

$$\gamma = \frac{T_p}{d}$$

where γ is a ratio of the peak rainfall intensity to the duration of a given storm event. This parameter also is a measure of the storm intensity in that large values of γ define short-duration-high-intensity storms while small values indicate that the storm event was relatively mild. (This is true only of the storms monitored during the Austin NURP study.)

Both of these parameters are a measure of runoff variability in that they define a relative degree of impact associated with not only the quantity of storm water runoff from a given area, but also the quality of that runoff. These data in conjunction with the interval between runoff events provides the basis for the predictive models proposed herein.

The data base for the predictive equations which describe both the runoff quantity and quality for storm events over the Northwest Austin and Rollingwood test watersheds are presented in Tables 28 and 29, respectively. These models are considered good representations of the established data base since the square of the multiple correlation coefficient (R^2), is of such a value that these equations can be said to explain the variation in the data. However, given that the number of observations is greater than the number of potential variables under consideration, the addition of a new variable will always increase R^2, but it will not necessarily increase the precision of the estimate of the response. Nevertheless, it is felt that adding the Υ term to the model has real significance, and the improvement in R^2 is not due to the fact that the number of parameters in the model is getting close to the saturation point.

The predictive equations were used to generate a series of curves which depict the change in the magnitude of the runoff coefficient and pollutant mass loads for both the Northwest Austin and Rollingwood sites. These curves reflect the impact associated with the change in such variables as rainfall intensity and days between runoff events. The curves presented in Figure 27 depict the change in the magnitude of the runoff coefficient for the Northwest Austin site for a variety of physical conditions. The model indicates that high-intensity-short-duration storms over the Northwest Austin watershed would experience runoff coefficients that are several times larger than lower-intensity-long-duration storms given the same antecedent conditions. Similar effects are apparent for the parameters COD, NH_3-N, and TSS as depicted in Figures 28 through 33 for the mass of pollutant discharged per acre per inch of rainfall.

The predictive equations for the quantity of NH_3-N removed during a storm event indicate that mass loads will be higher during low-intensity-long-duration storms which is consistent with the fact that this pollutant is largely associated with the liquid phase. On the other hand, the equations predict larger pollutant loads with high-intensity rainfalls for COD and TSS at the Northwest Austin site which is consistent with the fact that the quantity of these pollutants in storm water runoff is largely dependent on storm intensity. (Here the presence of COD and TSS in storm water runoff is a measure of the quantity of detritus displaced during a storm event.)

TABLE 28

DATA BASE FOR PREDICTIVE EQUATIONS FOR NORTHWEST AUSTIN WATERSHED

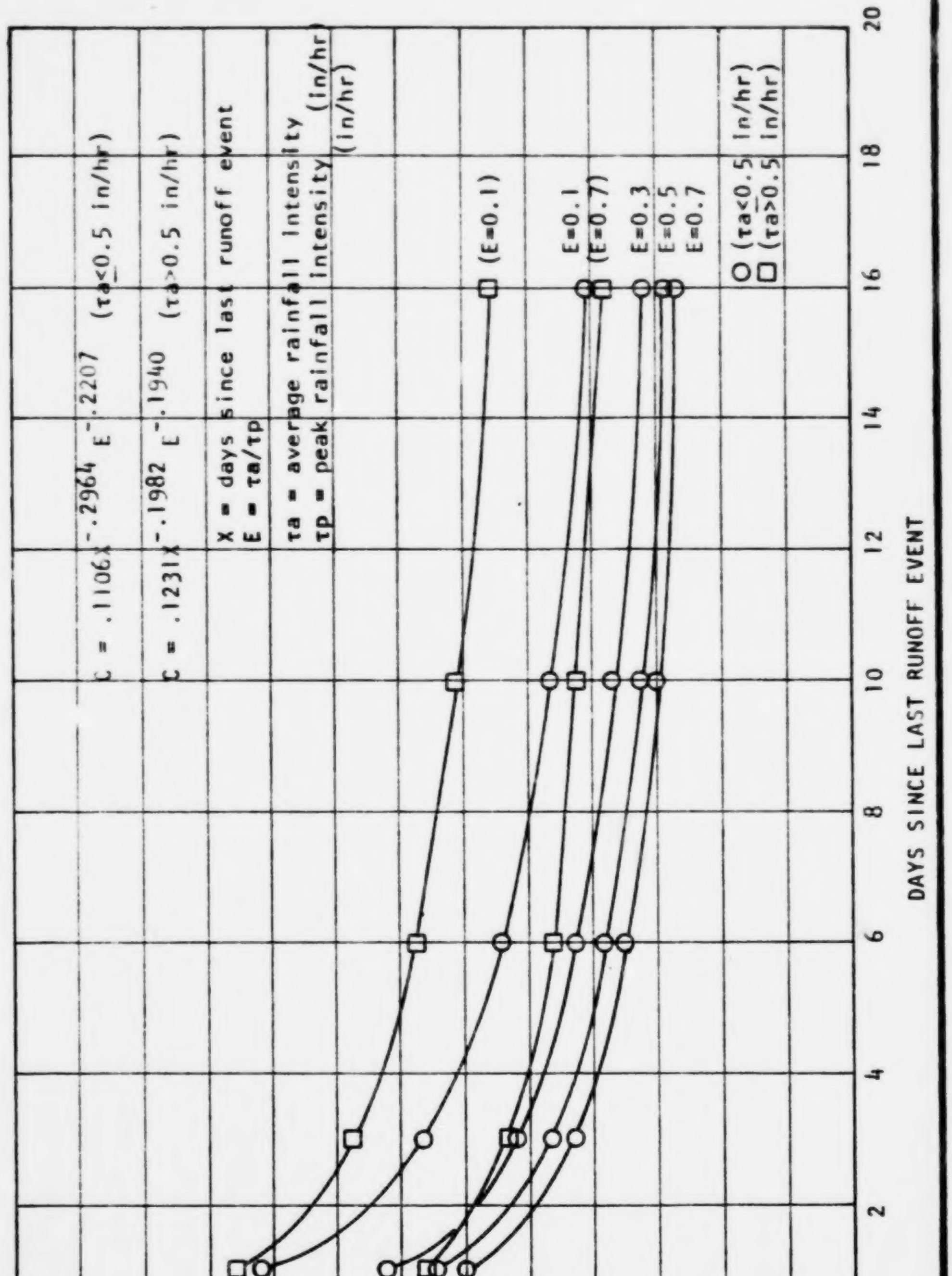
Parameter	Units	Number of Data Points	Range of Data Values	
			Low	High
Storm-Average Concentration				
TOC	mg/l	8	7.1	45.90
COD	mg/l	6	33.9	210.2
NH_3-N	mg/l	6	0.86	3.19
Total P	mg/l	10	0.09	1.00
TSS	mg/l	10	9.3	334.1
Rainfall	inches	16	0.13	4.32
Runoff Coefficient				
Ta ≤ 0.5 in/hr	-	9	0.046	0.190
Ta > 0.5 in/hr	-	7	0.082	0.148
E(Ta/Tp)	-	16	0.09	1.00
Ta	in/hr	16	0.04	2.16
Tp	in/hr	16	0.17	3.40
γ(Tp/d)	in/hr^2	16	0.04	6.00
Storm Duration (d)	hours	16	0.25	10.90

TABLE 29

DATA BASE FOR PREDICTIVE EQUATIONS FOR ROLLINGWOOD WATERSHED

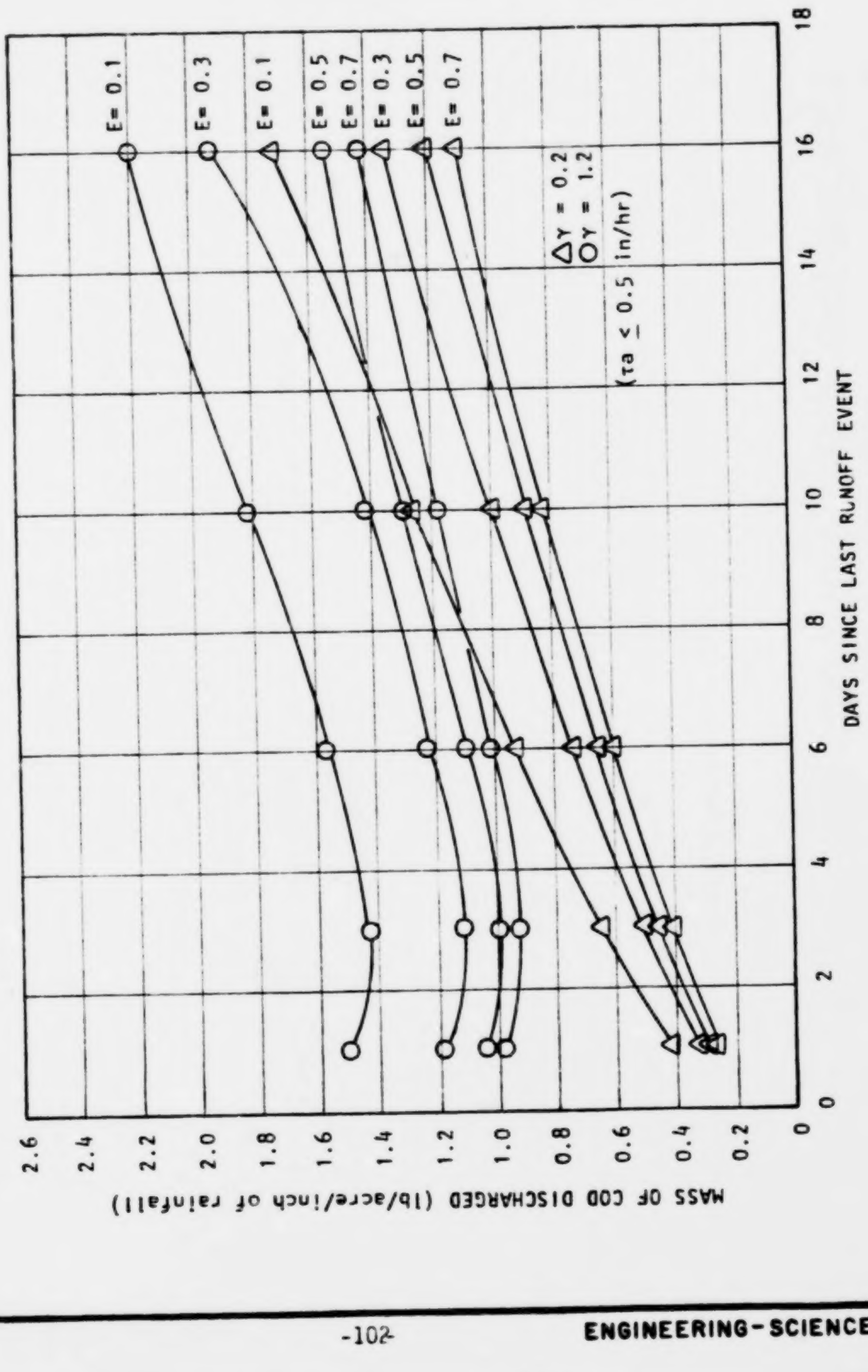
Parameter	Units	Number of Data Points	Range of Data Values	
			Low	High
Storm Average Concentration				
TOC	mg/l	8	8.6	63.2
COD	mg/l	8	35.7	145.3
NH_3-N	mg/l	8	0.78	2.18
Total P	mg/l	8	0.168	0.475
TSS	mg/l	8	37.3	377.7
Rainfall	inches	20	0.12	4.25
Runoff Coefficient				
Tp $\leq$ 1.10 in/hr	-	6	0.009	0.034
Tp > 1.10 in/hr	-	14	0.003	0.046
E(Ta/Tp)	-	20	0.03	0.93
Ta	in/hr	20	0.02	1.50
Tp	in/hr	20	0.16	8.00
Y(Tp/d)	in/hr^2	20	0.39	6.00
Storm Duration (d)	hours	20	0.25	5.70

NORTHWEST AUSTIN RUNOFF COEFFICIENT



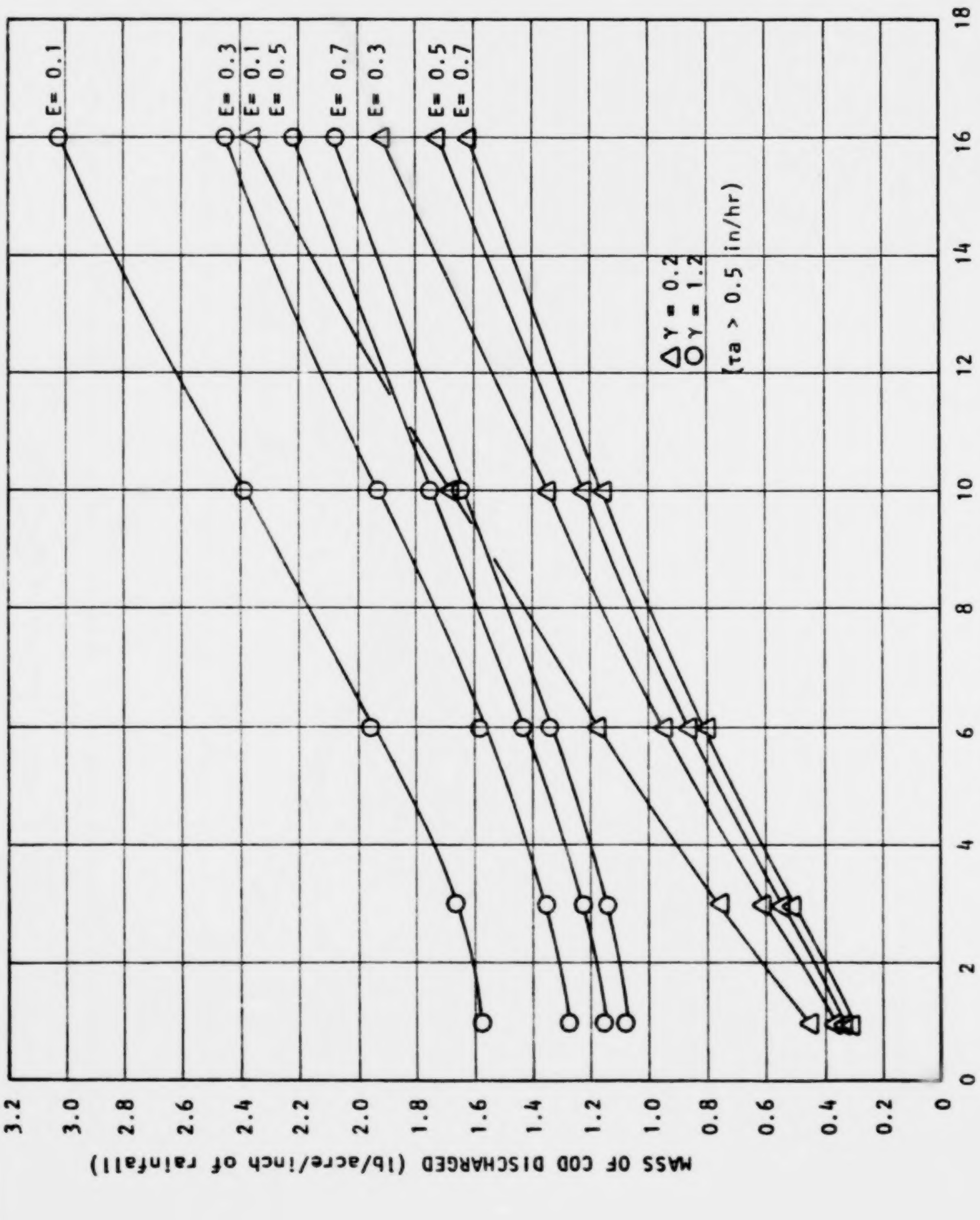
NORTHWEST AUSTIN COD

AVERAGE RAINFALL INTENSITY LESS THAN 0.5



NORTHWEST AUSTIN COD

AVERAGE RAINFALL INTENSITY GREATER THAN 0.5



NORTHWEST AUSTIN NH_3 -N

AVERAGE RAINFALL INTENSITY LESS THAN 0.5

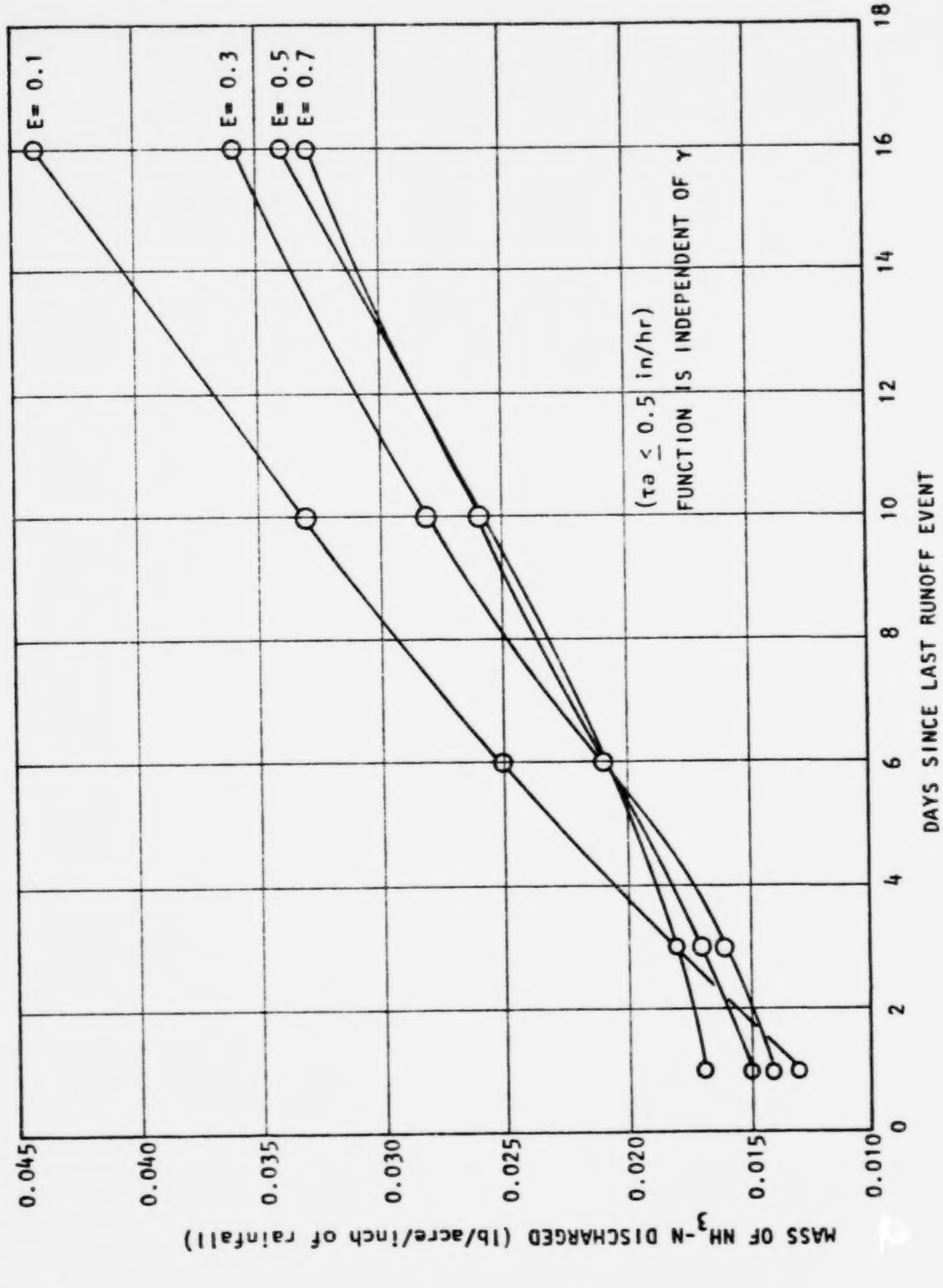


FIGURE 31

NORTHWEST AUSTIN NH_3 -N

AVERAGE RAINFALL INTENSITY GREATER THAN 0.5

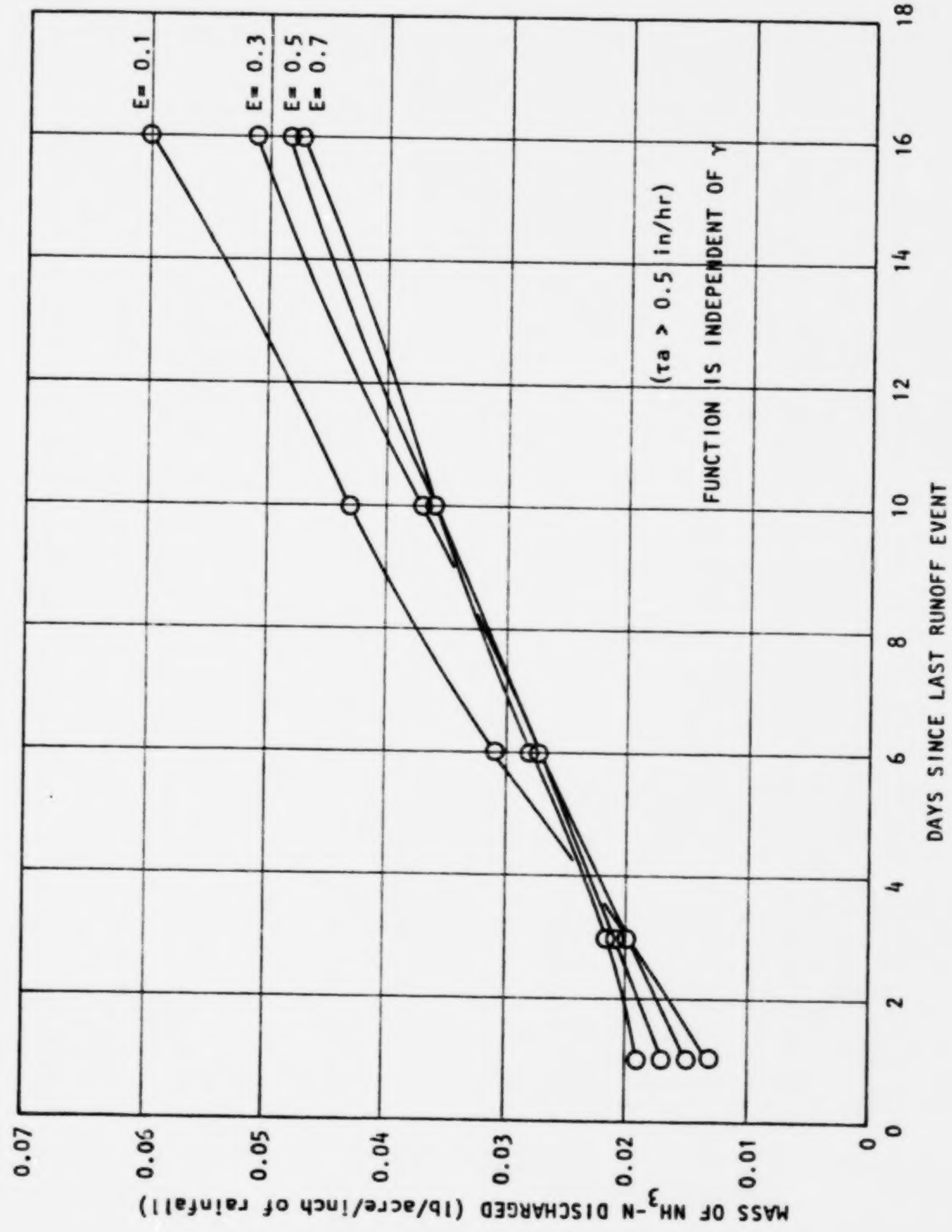


FIGURE 32

NORTHWEST AUSTIN TSS
AVERAGE RAINFALL INTENSITY
LESS THAN 0.5

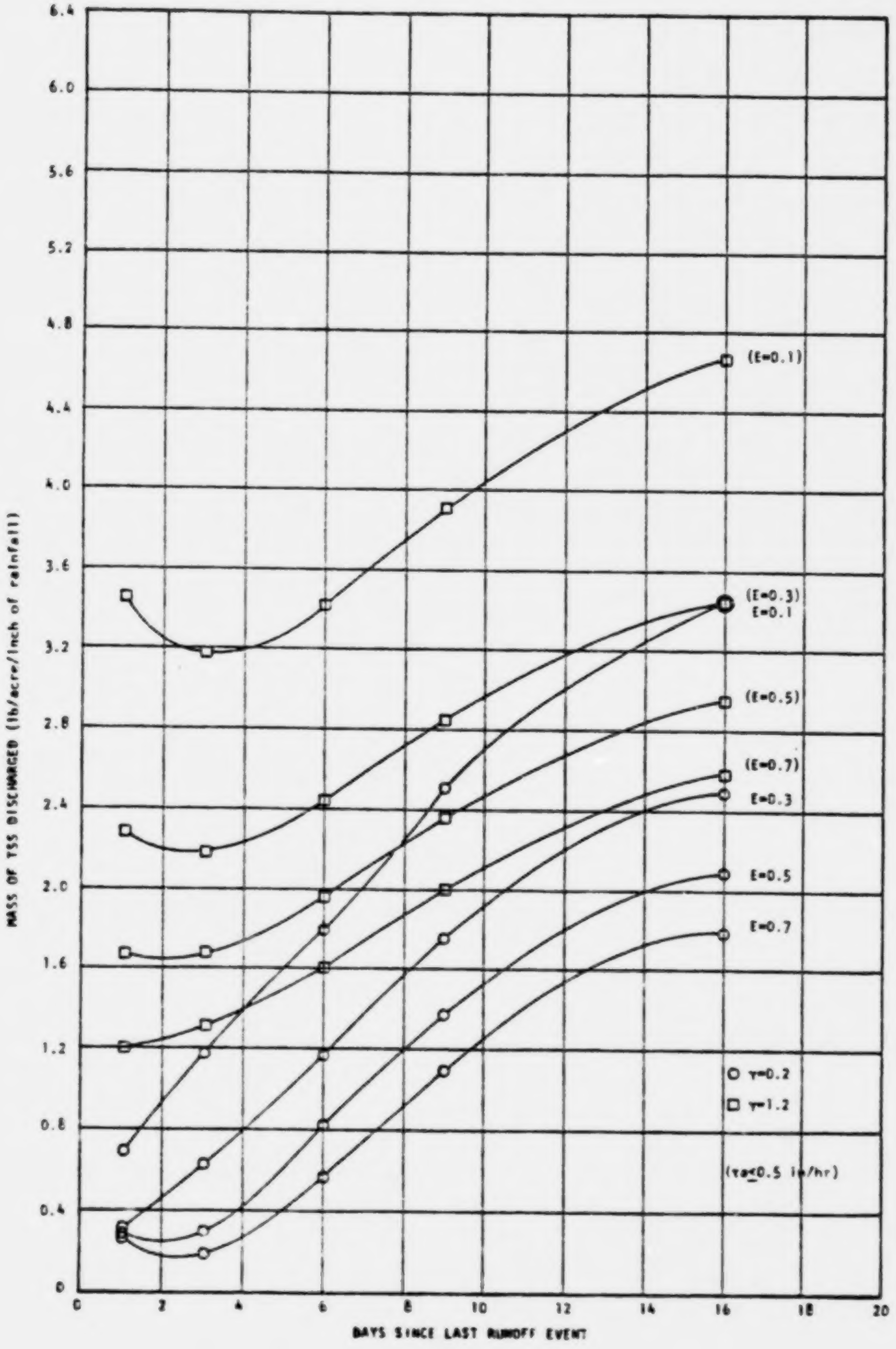
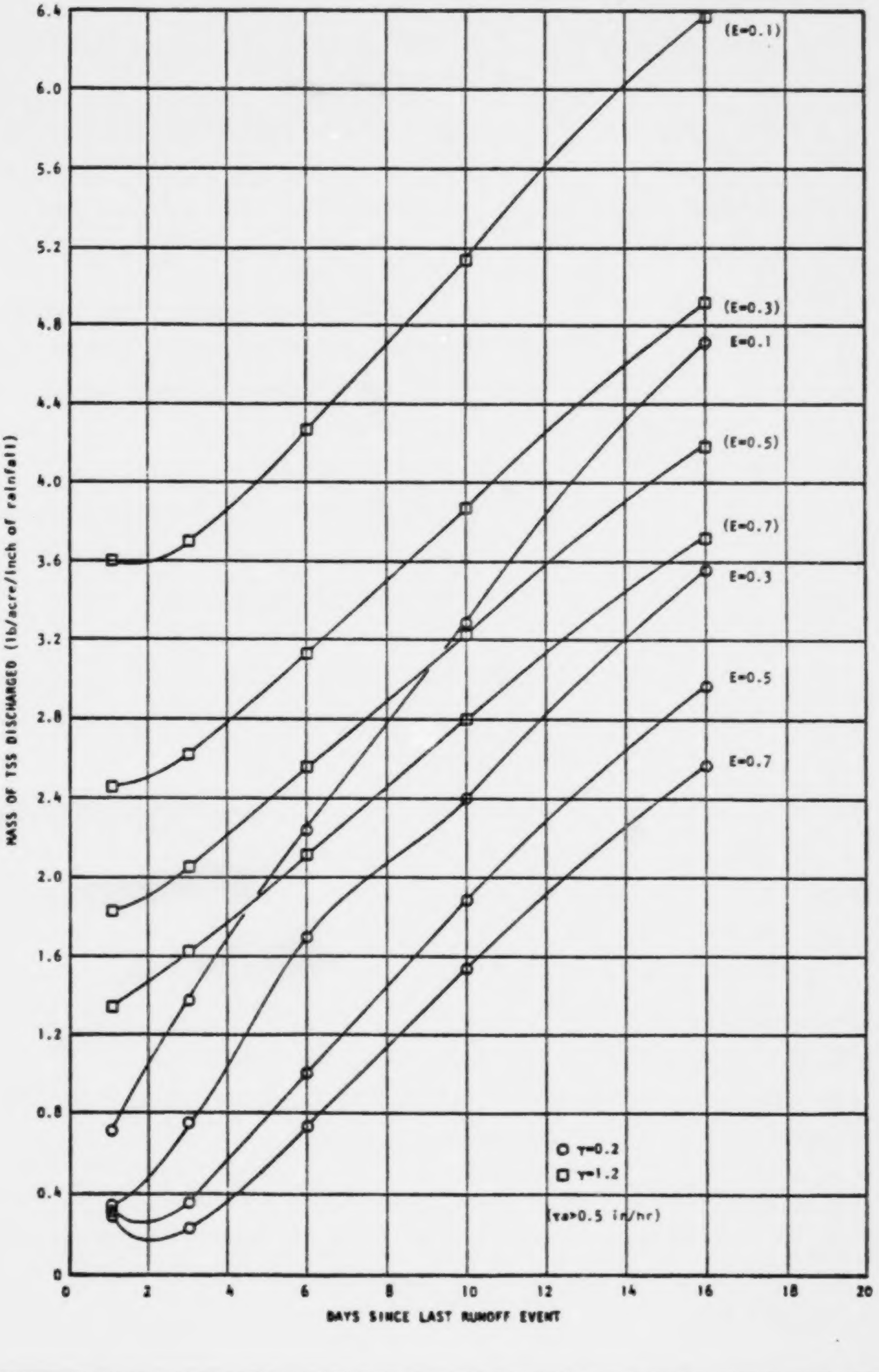


FIGURE 33

NORTHWEST AUSTIN TSS
AVERAGE RAINFALL INTENSITY
GREATER THAN 0.5



Similar curves are presented in Figure 34 which depict the change in the magnitude of the runoff coefficient for the Rollingwood site. These data representations, however, are not consistent with the information developed for the Northwest Austin site. Here the regression equations predict that lower intensity storms over the Rollingwood watershed would experience runoff coefficients that are slightly larger than higher intensity storms given the same antecedent condition. This apparent anomaly in the data representations for the Rollingwood site is consistent with the actual Austin NURP data record for this watershed. The predictive model is considered representative for the following reasons:

(1) Higher intensity storms at the Rollingwood site were usually associated with short duration rainfalls, hence, rainfall volumes were small and a larger fraction of these volumes would enter the soil horizon during a given event.

(2) High intensity rainfall often accounted for between 60 and 70 percent of the total rainfall volume for the majority of the storms monitored at the Rollingwood site, therefore, any estimate of an average storm intensity would be in gross error.

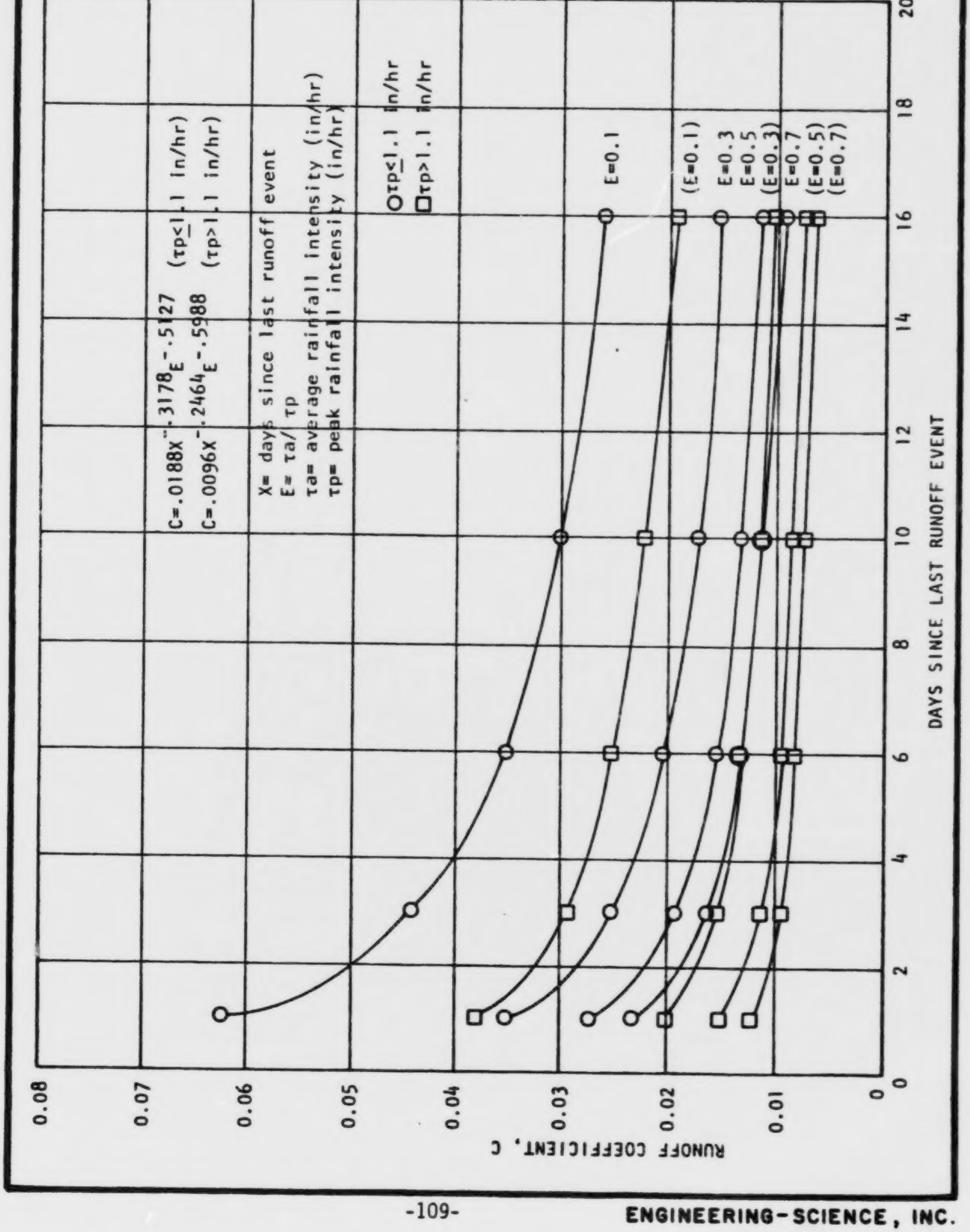
(3) Storm durations at the Rollingwood site were usually less than an hour, consequently rainfall volumes were small; and since the potential abstraction for this watershed was large, the associated runoff volumes were always low.

Pollutant loading predictions for the Rollingwood site relative to the mass of COD and NH_3-N removed from the ground during a given storm event are presented in Figures 35 through 38. These predictions follow from the projected runoff coefficient in that higher pollutant loadings are associated with slightly lower peak rainfall intensities. However, the curves for the two peak rainfall intensity conditions are grouped about the same, consequently, the two conditions are assumed to be, for all practical purposes, similar. Moreover, the general trend of these data representations is the same as that predicted for the Northwest Austin site.

Pollutant loading predictions for the Rollingwood watershed relative to the mass of TSS removed per acre per inch of rainfall are presented in Figures 39 and 40. Here again these data representations predict a shift in the trend of the magnitude of the total suspended solids load, such that the

FIGURE 34

ROLLINGWOOD RUNOFF COEFFICIENT



ROLLINGWOOD COD

PEAK INTENSITY LESS THAN 1.1

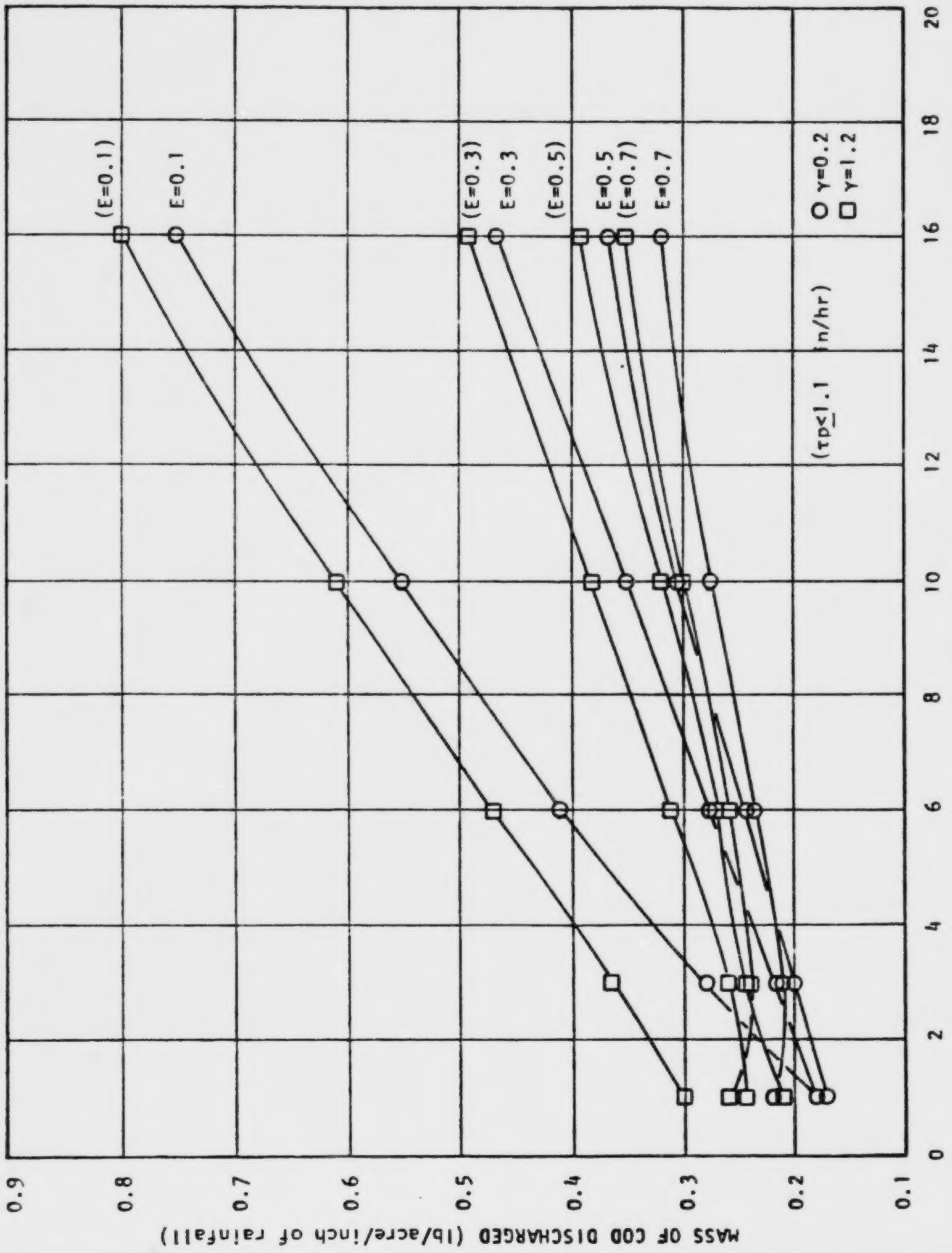
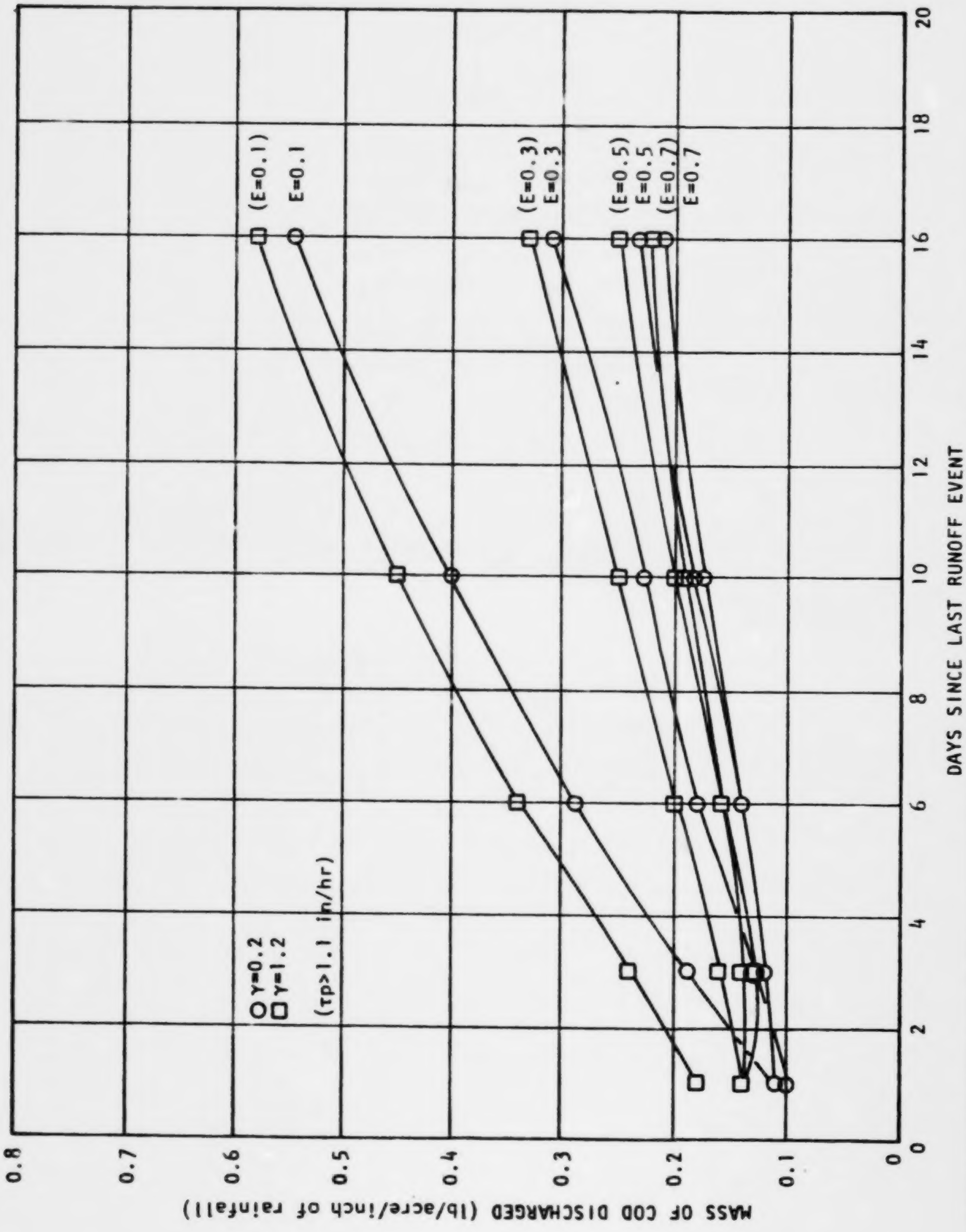


FIGURE 36

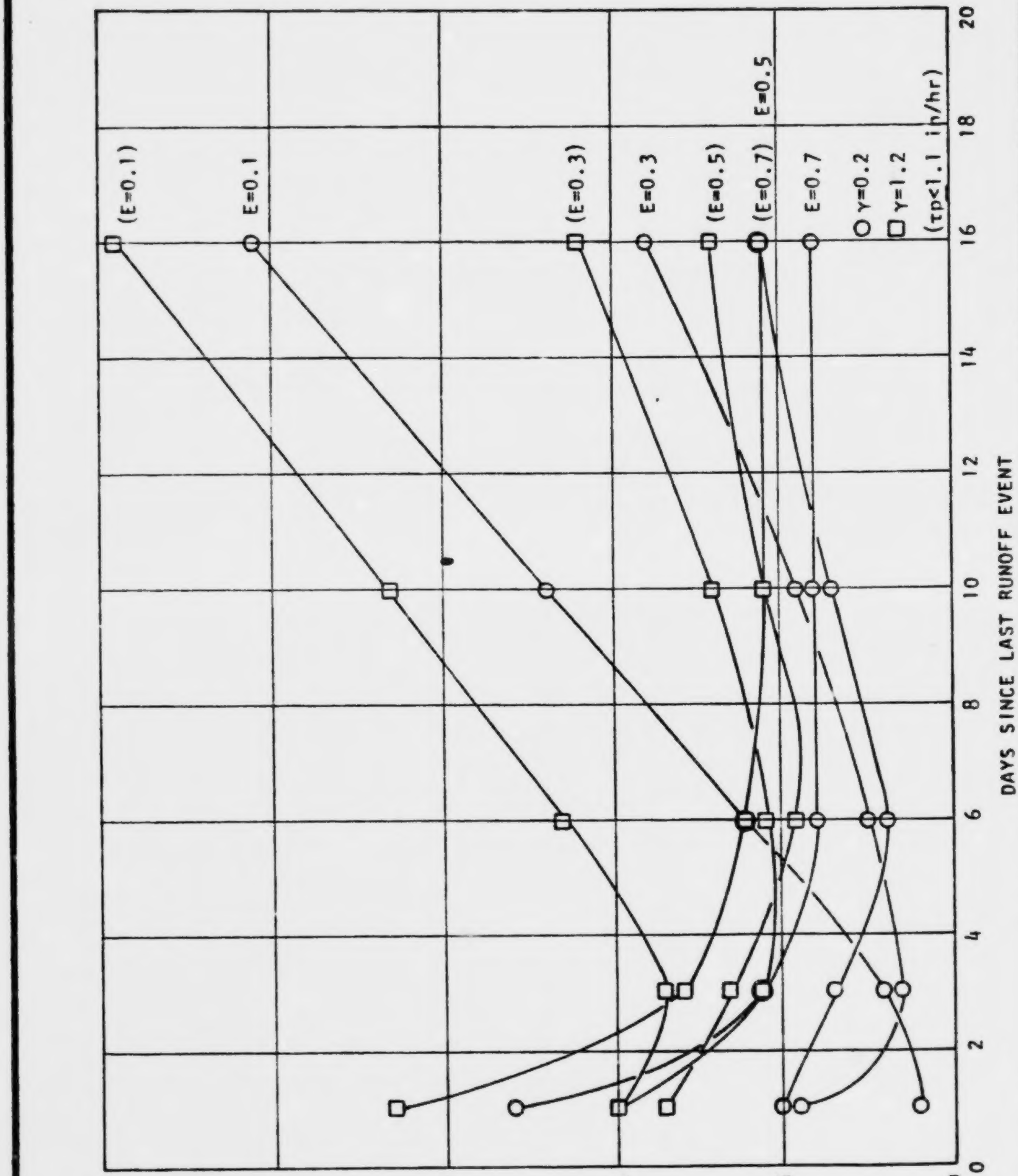
ROLLINGWOOD COD

PEAK INTENSITY GREATER THAN 1.1



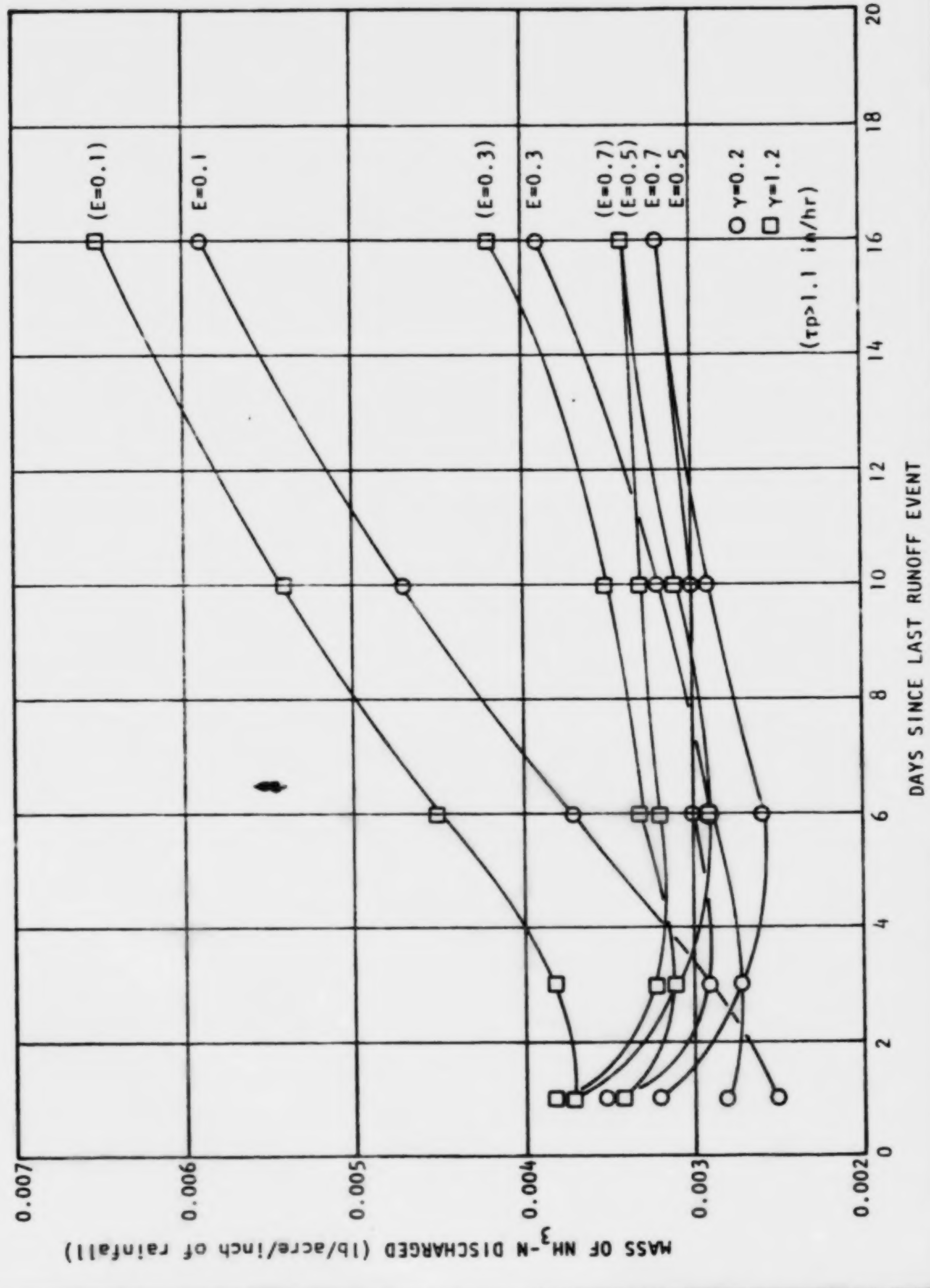
ROLLINGWOOD NH_3-N

PEAK INTENSITY LESS THAN 1.1

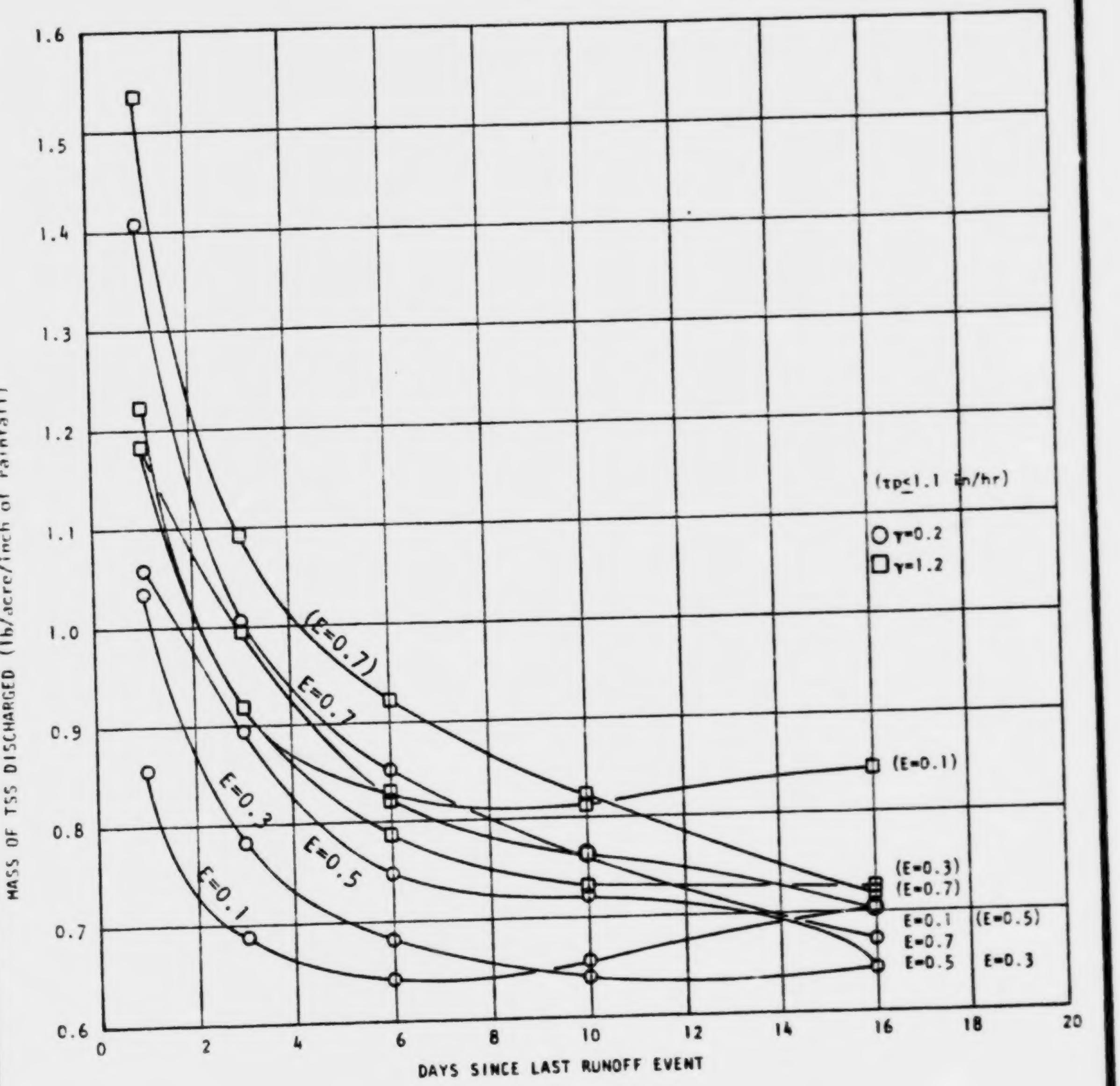


ROLLINGWOOD NH_3-N

PEAK INTENSITY GREATER THAN 1.1

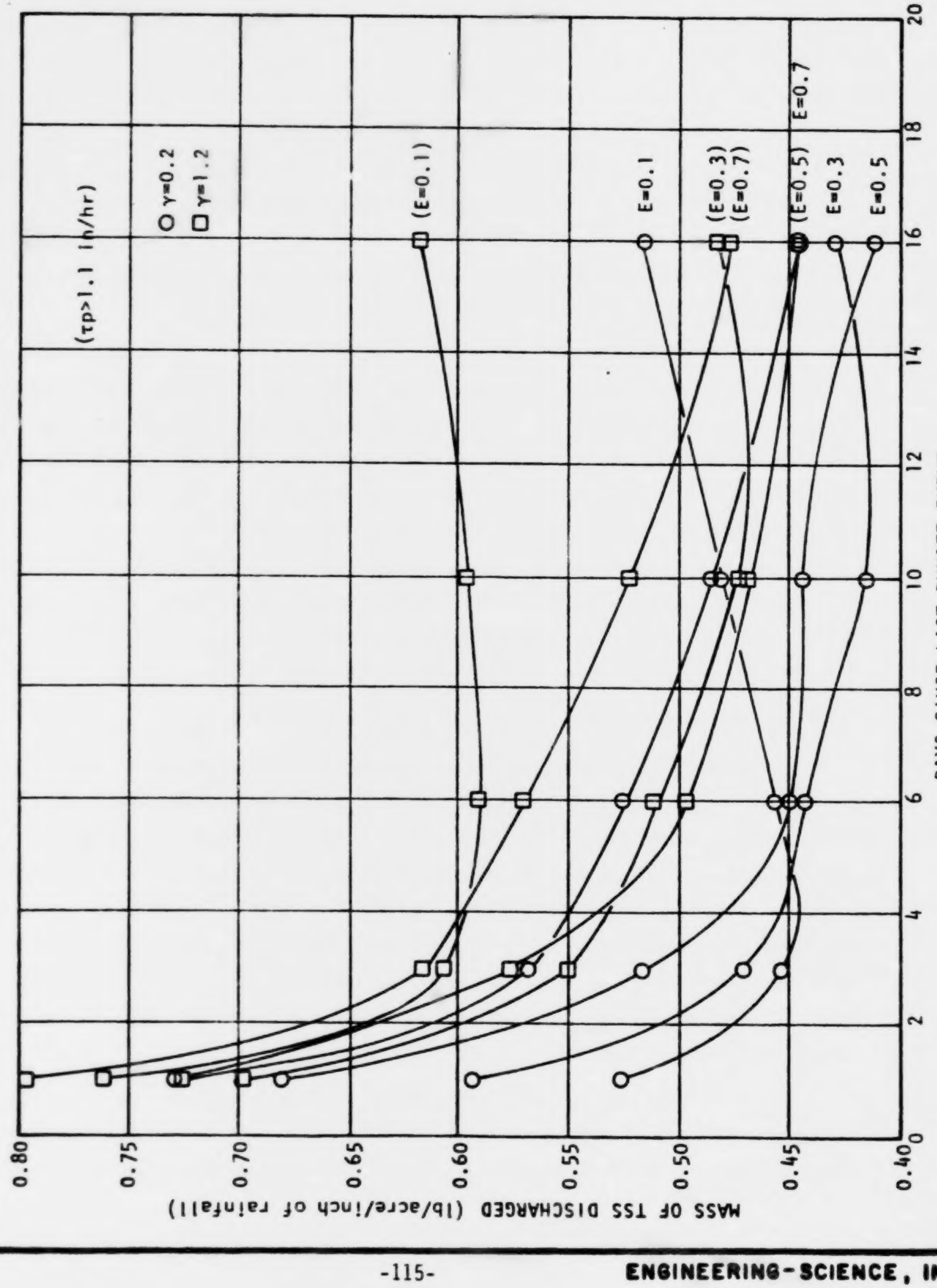


ROLLINGWOOD TSS
PEAK INTENSITY LESS THAN 1.1



ROLLINGWOOD TSS

PEAK INTENSITY GREATER THAN 1.1



prediction for the Rollingwood site is quite different from that predicted for the Northwest Austin watershed. However, these projections are consistent with the actual Austin NURP data record for the Rollingwood site. The shape of these curves are characteristic of the large potential abstraction associated with long antecedent dry periods, and the specific rainfall-runoff characteristics documented during the Austin NURP study for the Rollingwood site. However, the general trend of these predictive curves is for an increase in the mass of TSS discharged at protracted antecedent dry periods. (Apparently, the number of days between runoff events must be far in excess of 16 days for the Rollingwood site before the mass load will increase.) This trend is consistent with the Northwest Austin projections.

As was indicated by the pollutant mass load data presented in the aforementioned figures, even though the magnitudes of the storm-average concentrations (see Appendix D) for the various pollutants were the same for the two test watersheds, the mass discharged per acre per inch of rainfall was much greater for the Northwest Austin watershed than that projected for Rollingwood. This is because the Northwest Austin site would produce a larger volume of runoff during any given storm event. Depending on the quality parameter in question the mass discharged during a storm event from each acre in the Northwest Austin watershed would be five to ten times the mass discharged from each acre of the Rollingwood site.

Projected Annual Pollutant Loads From Test Watersheds

The monthly rainfall statistics for Austin (U.S. Weather Service data collected at Austin Airport between 1949 and 1974) are presented in Table 30. These data are compared with the monthly rainfall statistics developed for storm events monitored during the Austin NURP study. In general, the NURP study monitored rainfall events which were characteristic of a wet year in which both the average rainfall intensity and the volume of rainfall per storm were greater than the magnitude of the mean of the statistical record. However, the antecedent dry periods between storms for the NURP study were longer on average than the historical record.

The U.S. Weather Service record in conjunction with the predictive equations developed in the previous section were used to estimate both the average monthly and annual cumulative pollutant loads from the test water-

TABLE 30

MONTHLY RAINFALL STATISTICS FOR AUSTIN*

Month	Number of NURP Storms	Storm Duration (hours)		Average Intensity (inches/hour)		Volume/Storm (inches)		Time Between Storms (hours)	
		Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation
January		4.66**	5.98	0.027	0.037	0.17	0.42	82	140
	0	(NO NURP STORMS IN JANUARY)							
February		5.40	6.09	0.041	0.065	0.29	0.59	72	94
	(2)	(NO NURP INTENSITY OR DURATION DATA AVAILABLE)				(0.31)	(0.04)	(72)	(NA)
March		3.33	3.18	0.060	0.096	0.20	0.33	96	115
	(4)	(3.84)***	(3.08)	(0.299)	(0.302)	(0.73)	(0.90)	(165)	(154)
April		3.74	3.38	0.086	0.139	0.35	0.54	88	131
	(3)	(1.72)	(1.99)	(0.345)	(0.242)	(0.34)	(0.20)	(208)	(241)
May		3.16	2.89	0.115	0.156	0.40	0.59	78	102
	(6)	(2.46)	(1.95)	(0.989)	(0.820)	(1.75)	(1.85)	(138)	(130)
June		3.29	3.81	0.103	0.134	0.41	0.73	87	143
	(9)	(4.53)	(5.47)	(0.457)	(0.335)	(1.49)	(1.88)	(68)	(81)
July		2.34	1.81	0.131	0.400	0.28	0.53	133	178
	(6)	(0.59)	(0.46)	(1.042)	(0.664)	(0.64)	(0.68)	(105)	(184)
August		3.25	3.19	0.102	0.129	0.37	0.64	126	189
	(3)	(1.48)	(0.67)	(0.239)	(0.146)	(0.30)	(0.13)	(271)	(364)
September		4.48	5.20	0.088	0.110	0.44	0.83	87	130
	(3)	(0.83)	(0.29)	(0.533)	(0.058)	(0.43)	(0.12)	(168)	(204)
October		4.41	4.66	0.093	0.118	0.48	0.92	100	134
	-	(NO NURP STORMS IN OCTOBER)							
November		5.15	6.48	0.044	0.067	0.30	0.65	106	150
	-	(NO NURP STORMS IN NOVEMBER)							
December		5.22	5.88	0.036	0.044	0.25	0.51	92	144
	-	(NO NURP STORMS IN DECEMBER)							

*NURP data are in parentheses.

**U.S. Weather Service data collected at Austin Airport from 1949 to 1974.

***Austin NURP statistics are the average of data collected by the Rollingwood, Northwest Austin, and USGS rain gauges.

sheds. These data are presented in Table 31, and are based on both the predicted runoff coefficients and the storm-average concentrations associated with the average monthly storms (based on the number of storms per month and the total rainfall volume) estimated from the historical record.

The estimated annual cumulative pollutant loads from the Northwest Austin and Rollingwood sites were based on a long-term average rainfall volume for the Austin area. It is emphasized that the actual pollutant loadings will in all probability vary greatly from these values for any given year. For instance, a dry year would result in much lower cumulative pollutant loads from either test watershed while a wet year would produce higher cumulative pollutant loads. (Since the Austin NURP data record was characteristic of a wet year including a major flood, the projected annual cumulative pollutant loads may, in fact, be higher than average.)

Pollutant Washoff Rate From Test Watersheds

Information relative to the average pollutant washoff from both the Northwest Austin and Rollingwood watersheds during a given storm event is presented in Table 32. These estimates were developed from runoff quantity and quality data from the NURP test watersheds, and are thought representative of typical Austin residential development. It was assumed that these pollutant mass washoff rates would fit a log-normal probability distribution as did the instantaneous pollutant concentration data for the same areas (see Appendix A). The values were developed from data for measured pollutant loads from the test watersheds and therefore represent that portion of the accumulated pollutant mass actually washed from the watershed.

Woodhollow Dam Storm Water Retention Basin

The Woodhollow Dam retention basin acts as a storm water retention device and was the only structural control alternative evaluated during the NURP study. The dam is located on Woodhollow Drive in the Northwest Austin watershed just downstream of the Hart Lane sampling site. The Hart Lane and Woodhollow Drive sampling sites were located at the inlet and outlet points to the retention basin, respectively. The objective of this part of the Austin NURP study was to determine what effect, if any, the basin had upon storm water runoff quality in the Northwest Austin watershed.

TABLE 31

ESTIMATED AVERAGE MONTHLY POLLUTANT LOADS FROM TEST WATERSHEDS

Month	Parameter in lbs/acre*				
	TOC	COD	NH_3-N	Total P	TSS
January	0.11/0.70**	0.40/2.20	0.008/0.038	0.0011/0.0078	1.58/3.73
February	0.24/1.40	0.84/4.21	0.018/0.071	0.0025/0.0147	3.48/7.09
March	0.11/0.63	0.41/2.07	0.008/0.037	0.0011/0.0076	1.51/3.56
April	0.21/1.21	0.76/3.90	0.016/0.068	0.0021/0.0141	2.92/6.65
May	0.27/1.70	0.95/5.27	0.02/0.091	0.0027/0.0187	3.82/8.93
June	0.25/1.45	0.90/4.63	0.019/0.081	0.0026/0.0167	3.50/7.88
July	0.12/0.61	0.45/2.25	0.008/0.042	0.0012/0.0088	1.47/3.96
August	0.16/0.84	0.61/3.03	0.011/0.056	0.0016/0.0118	2.00/5.31
September	0.27/1.56	1.18/4.96	0.02/0.087	0.0027/0.0179	3.76/8.46
October	0.25/1.43	0.92/4.79	0.018/0.086	0.0025/0.0178	3.36/8.26
November	0.15/0.85	0.55/2.89	0.011/0.052	0.0015/0.0108	1.96/5.00
December	0.15/0.85	0.53/2.74	0.011/0.048	0.0015/0.01	2.02/4.66
Total	2.29/13.23	8.50/42.94	0.168/0.757	0.0231/0.1567	31.38/73.52

*Based on predicted average runoff volumes and storm-average concentrations where the runoff coefficient was estimated from Figure 24 using the interval between storms presented in Table 30. The value of Y was taken as 1.2 and the value of E as 0.5. The number of storms per month was estimated based on the data presented in Table 30.

**No./No. = Rollingwood Site/Northwest Austin Site.

TABLE 32

ESTIMATED AVERAGE POLLUTANT WASHOFF FROM TEST WATERSHEDS

	Rollingwood Site		Northwest Austin Site		Combination of Two Sites*	
Pollutant	Median (lbs/day/acre)	Log Normal Standard Deviation	Median (lbs/day/acre)	Log Normal Standard Deviation	Median (lbs/day/acre)	Log Normal Standard Deviation
COD	0.038	1.38	0.079	1.58	0.056	1.50
TOC	0.013	1.04	0.024	1.49	0.018	1.32
NH_3-N	0.0007	1.33	0.0017	1.33	0.0011	1.44
Total P	0.0001	1.39	0.0005	1.27	0.0003	1.41
TSS	0.086	1.56	0.1260	1.45	0.108	1.47

*Based on all storm water runoff data from both the Rollingwood and Northwest Austin sites.

The performance of the Woodhollow Dam stormwater retention basin was examined by monitoring both flow and runoff pollutant concentrations at the Hart Lane and Woodhollow Drive survey stations. A pictorial representation of the storm water retention basin including both inflow and outflow monitoring stations is presented in Figure 41. The maximum storage capacity of the basin (up to the trash screen) is approximately 17.5 acre-ft of volume. The actual volume of storm water under retention storage at any given time was a function of the number of dry days between rainfall events, because water would be lost to evaporation and infiltration during this period. (Due to these water losses from the basin, several of the Austin NURP storm events did not produce sufficient outflow volume to provide data for an assessment of retention basin treatment performance.) Obviously, the pollutant removal capacity of the Woodhollow Dam retention basin was a function of the available retention storage prior to a given runoff event. The retention basin did have the capacity to pass flows continuously through the system during a rainfall event, however, extensive basin bottom scour would often produce higher suspended solids loads in the effluent than that monitored in the influent to the dam. Consequently, it was elected to maintain a fixed amount of retention storage in the basin in order to reduce the slope of the hydraulic gradient in the channel upstream of the dam which would reduce the magnitude of the influent velocities through the system. A range of probable hydraulic detention times for the Woodhollow Dam structure associated with 0.5 inches of runoff volume into the retention basin are presented in Table 33, however, only two storm events over the Northwest Austin site produced in excess of this runoff volume during the Austin NURP study.

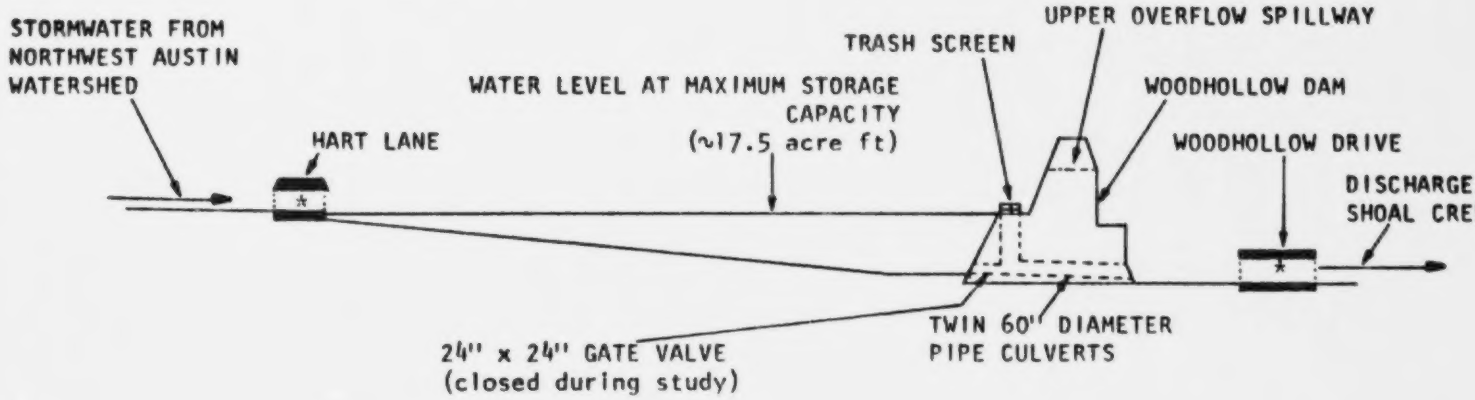
A listing of the available survey data for the pollutant mass inflows and outflows developed from the storm water sampling survey of the Woodhollow Dam is presented in Table 34. These data indicate considerable variation in the pollutant removal efficiencies associated with the operation of the retention basin.

The storm event monitored on 9/14/81 followed a period of extended dryness, consequently, the retention basin was nearly empty at the time of this event. Therefore, a significant portion of the overall pollutant removal was probably accomplished by the extended retention of storm water in the basin. The storms recorded on 3/7/81 and 9/15/81 followed rainfall events

FIGURE 41

PICTORIAL OF

THE WOODHOLLOW STORMWATER DETENTION BASIN


STORMWATER FROM
NORTHWEST AUSTIN
WATERSHED
HART LANE
WATER LEVEL AT MAXIMUM STORAGE
CAPACITY
(~17.5 acre ft)
TRASH SCREEN
UPPER OVERFLOW SPILLWAY
WOODHOLLOW DAM
WOODHOLLOW DRIVE
DISCHARGE TO
SHOAL CREEK
24'' x 24'' GATE VALVE
(closed during study)
TWIN 60'' DIAMETER
PIPE CULVERTS
*
*

NOTE : NOT TO SCALE

* - STORMWATER MONITORING STATION

TABLE 33

THEORETICAL HYDRAULIC DETENTION IN THE WOODHOLLOW DAM STORM WATER RETENTION BASIN

Duration of Runoff Event (hours)	Flow Rate to Retention Basin (cfs)*	Hydraulic Detention (hours)**
1.5	126.9	1.67
2.0	95.2	2.23
2.5	76.1	2.78
3.0	63.5	3.36
4.0	47.6	4.47
6.0	31.7	6.67
8.0	23.8	8.90

*Associated with 0.5 inches of runoff volume.

**Basin has approximately 17.5 acre-feet of permanent storage below the inverts of the two spillway culverts. This permanent storage was assumed completely utilized at time of storm.

TABLE 34

REMOVAL OF POLLUTANT MASS IN THE WOODHOLLOW DAM RETENTION BASIN

Date	Pollutant	Mass In (lbs)	Mass Out (lbs)
3/07/81	COD	95.6	91.5
	TOC	20.0	24.8
	NH_3-N	3.4	2.5
	Total P	0.54	0.45
	TSS	122	41
9/14/81	TOC	50.2	10.7
	Total N	19.49	3.56
	Total P	0.74	0.29
	TSS	479	73
9/15/81	TOC	63.0	160.5
	Total N	29.56	28.93
	Total P	1.47	1.84
	TSS	244	544

which occurred within several days of the monitored event, consequently, the basin was at or near its maximum retention storage. However, the data from these two storms do not present a clear picture of the pollutant removal efficiency for the retention basin because there are only two data points from which to make an evaluation. Statistical data for the storm average pollutant concentrations developed from instantaneous water quality samples collected at the Woodhollow Drive survey station indicate that the retention basin did, in fact, reduce the pollutant loads generated during most of the storms surveyed.

However, additional storm water runoff from approximately 80 acres which contains apartment complexes and their associated parking areas flows directly into the retention basin through roof and curb drains. It is estimated that the actual pollutant mass entering the basin during a given storm event might exceed 130 percent of that measured at the Hart Lane survey station. Consequently, the overall treatment efficiencies associated with the operation of the Woodhollow Dam retention basin are probably much higher than the reported values. However, the extent of this removal cannot be quantified given available data. Therefore, it is suggested that the storm water survey at the Woodhollow Dam continue for an unspecified time period in order to obtain sufficient information to accurately assess the treatment performance of this control structure.

Settling Characteristics of Northwest Austin Storm Water Runoff

A settling test was performed on a sample of storm water runoff from the Northwest Austin site. Test results are presented in Table 35. Observations made during the test indicated that the larger particles which consisted primarily of suspended mineral material, settled rapidly while other solids remained in suspension for longer periods. Particles which exhibited poor settling characteristics were composed primarily of fine organic material (vegetable detritus) which settled slowly. Large fractions of the suspended matter were removed within 4.5 hours of the start of the settling test. This retention period is within the likely range of hydraulic retention times associated with the operation of the Woodhollow Dam retention basin (see Table 33).

TABLE 35

SETTLING COLUMN TEST RESULTS

Column Depth (feet)	Concentration of Suspended Solids in Settling Column*				
	T-10**	T-30	T-60	T-90	T-270
0.5	460	160	150	87	20
1.0	320	190	330	15	50
1.5	290	250	60	220	-
2.0	90	130	70	260	-
2.5	280	140	100	40	90
3.0	250	130	70	30	70
3.5	170	120	90	40	60
4.0	140	150	60	60	50
4.5	230	90	146	130	30
5.0	170	180	111	170	150
5.5	230	120	140	110	190
6.0	108	110	130	100	30

*All values in mg/l.

**T is zero time (minutes); T-10 is ten minutes into test; T-30 is thirty minutes into test; etc.

Sample collected on 7/8/81 from Hart Lane Survey Station upstream from the Woodhollow Dam retention basin.

Austin NURP Toxic Pollutant Sampling

Selected storm water runoff samples collected during the Austin NURP study were analyzed for the presence of metals and other toxic substances. The designated survey parameters were lead, zinc, mercury, arsenic, cadmium, copper, defoliants, insecticides, and total hydrocarbons. A listing of the specific toxic organic compounds examined during the study and the detection limits used in the analysis of both organics and metals is presented in Table 36.

A summary of the results of the metals analyses performed on storm water runoff samples from the Northwest Austin, Rollingwood, and Woodhollow Dam sites is presented in Table 37. There were several sets of analyses which utilized different detection limits for the various metal species and these data were grouped as depicted in Table 37. In general, most of the metals were reported at concentration levels below the detection limit, however, both lead and zinc were present at detectable levels in runoff from the three survey sites. (Detectable levels of lead and zinc were not unexpected since this is a phenomenon of urban development.) Special metals surveys were conducted for the U.S. EPA Monitoring and Data Support Division (MDSD) and these data also are presented in Table 37. The MDSD survey included analyses for some 29 metals and the results of these analyses for samples collected at the Hart Lane and Rollingwood survey stations are presented in Appendix F to this report. The storm water runoff from both the Northwest Austin and Rollingwood sites show moderate levels of calcium, magnesium, sodium, and potassium which is characteristic of the normal runoff quality from the survey watersheds. The significance of the MDSD survey results must be weighed in the light of results obtained from other NURP studies, therefore, further comment is withheld at this time.

A summary of the results of the toxic organics analyses performed on storm water runoff samples from the Northwest Austin, Rollingwood, Woodhollow Dam, and Turkey Creek Sites is presented in Table 38. These data were grouped into sets relative to the detection limits used in the analysis. In addition to the analyses for the presence of defoliants and insecticides in Austin storm water runoff, priority pollutant analysis was conducted on samples collected from both the Northwest Austin and Rollingwood sites. A summary of the apparent priority pollutants present in flow weighted composites and

TABLE 36

TOXIC ORGANIC COMPOUNDS AND METALS IN STORM WATER RUNOFF SAMPLES

	Detection Limit (ppb)
Metals	
Lead	50
Zinc	5
Mercury	5
Arsenic	30
Cadmium	5
Copper	5
Toxic Organics	
Total Hydrocarbons	10
Defoliants	
Total 2,4-D	2
Total 2,4,5-T	2
Insecticides	
Total Chlordane	4
Total DDT	1
Total DDE	1
Total DDD	1
Total Diazinon	10
PCBs	5

TABLE 37

SUMMARY OF METALS ANALYSES PERFORMED ON RUNOFF SAMPLES

	Rollingwood				Woodhollow Dam				Northwest Austin			
	1	2	3	4	1	2	3	4	1	2	3	4
ES Metals I												
Arsenic	1/4	<30-70	<30	30	3/14	<30-70	<30	30	1/2	<30-40	<30	30
Copper	3/4	<5-11	7	5	5/14	<5-16	<5	5	2/2	16-160	88	5
Cadmium	0/4	<1	<1	1	1/14	<1-1.3	<1	1	0/2	<1	<1	1
Mercury	0/1	<5	-	5	0/1	<5	-	5	-	-	-	-
Lead	3/4	<50-340	130	50	1/14	<50-110	<50	50	2/2	140-890	515	50
Zinc	4/4	41-134	65	5	14/14	22-46	35	5	2/2	57-510	284	5
ES Metals II												
Arsenic	-	-	-	-	-	-	-	-	-	-	-	-
Copper	7/8	<5-42	11	5	2/2	8-15	11.5	5	4/5	<5-42	34	5
Cadmium	0/8	<5	<5	5	0/2	<5	<5	5	0/5	<5	<5	5
Mercury	-	-	-	-	-	-	-	-	-	-	-	-
Lead	6/8	<50-390	115	50	2/2	70-180	125	50	4/5	<50-270	100	50
Zinc	8/8	8-155	51	5	1/2	<5-22	-	5	5/5	15-100	52	5
Priority Pollutant Metals												
Arsenic	1/2	<5-4.3	-	5,1	-	-	-	-	1/2	<5-3.3	-	5,1
Copper	1/2	12-<20	-	5,20	-	-	-	-	1/2	<20-25	-	20
Cadmium	0/2	<5	<5	5	-	-	-	-	0/2	<5	<5	5
Mercury	0/2	<5	<5	5	-	-	-	-	0/2	<5	<5	5
Lead	2/2	37.6-140.1	89	10	-	-	-	-	2/2	60.5-126	93.3	10
Zinc	2/2	10-64	37	5	-	-	-	-	2/2	29-99	64	5
MDSD Special Metals												
Arsenic	0/4	<10	<10	10	0/1	<10	-	10	0/3	<10	<10	10
Copper	0/4	<20	<20	20	0/1	<20	-	20	3/3	30-80	40	20
Cadmium	1/4	<5-40	<5	5	0/1	<5	-	5	0/3	<5	<5	5
Mercury	0/4	<1	<1	1	0/1	<1	-	1	0/3	<1	<1	1
Lead	2/3	<40-130	120	40	1/1	80	-	40	3/3	210-320	220	40
Zinc	2/3	<10-70	40	10	1/1	5,760	-	10	3/3	80-160	100	10

KEY: Column 1 = number of samples above detection limit/total number of samples analyzed.

Column 2 = range of concentrations reported (μg/l).

Column 3 = median concentration value (μg/l).

Column 4 = detection limit (μg/l).

MDSD = U.S. EPA Monitoring and Data Support Division.

Priority Pollutant Metals - analysis performed by Spectrix Corporation in Houston, Texas.

TABLE 38

SUMMARY OF TOXIC ORGANICS ANALYSES PERFORMED ON RUNOFF SAMPLES

Compound	Northwest Austin				Woodhollow Dam				Rollingwood				Turkey Creek			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
ES Organics I																
Diazinon	-	-	-	-	0/8	<10	<10	10	0/1	<10	-	10				
Chlordane	-	-	-	-	0/8	<4	<4	4	0/1	<4	-	4				
p,p' DDT	-	-	-	-	0/8	<1	<1	1	0/1	<1	-	1				
p,p' DDD	-	-	-	-	0/8	<1	<1	1	0/1	<1	-	1				
p,p' DDE	-	-	-	-	0/8	<1	<1	1	0/1	<1	-	1				
PCBs	-	-	-	-	0/8	<5	<5	5	0/1	<5	-	5				
2,4-D	-	-	-	-	0/8	<2	<2	2	0/1	<2	-	2				
2,4,5-T	-	-	-	-	0/8	<2	<2	2	0/1	<2	-	2				
C_4-C_{12}*	1/9	<10-69	-	10	2/27	<10-51	-	10	-	-	-	-				
Benzene	0/1	<10	-	10	0/3	<10	<10	10	-	-	-	-				
ES Organics II																
Diazinon	0/2	<.01	-	.01	0/2	<.01	-	.01	0/5	<.01	-	.01	0/1	<.01	-	.01
Chlordane	0/2	<.01	-	.01	0/2	<.01	-	.01	0/5	<.01	-	.01	0/1	<.01	-	.01
p,p' DDT	0/2	<.01	-	.01	0/2	<.01	-	.01	0/5	<.01	-	.01	0/1	<.01	-	.01
p,p' DDD	0/2	<.01	-	.01	0/2	<.01	-	.01	0/5	<.01	-	.01	0/1	<.01	-	.01
p,p' DDE	0/2	<.01	-	.01	0/2	<.01	-	.01	0/5	<.01	-	.01	0/1	<.01	-	.01
PCBs	0/2	<.01	-	.01	0/2	<.01	-	.01	0/5	<.01	-	.01	0/1	<.01	-	.01
2,4-D	2/2	.23-1.3	.77	.03	2/2	.10-.19	.15	.03	4/5	<.03-.36	.06	.03	0/1	<.03	-	.03
2,4,5-T	2/2	.08-.14	.11	.03	2/2	<.03-.05	.04	.03	4/5	<.03-.05	.04	.03	1/1	.06	-	.03
C_4-C_{12}*	-	-	-	-	0/18	<.01	-	.01	0/18	<.01	-	.01	0/18	<.01	-	.01
Benzene	-	-	-	-	0/2	<.01	-	.01	0/2	<.01	-	.01	0/2	<.01	-	.01
Priority Pollutants																
Diazinon	0/4	ND	-	10					0/4	ND	-	10				
Chlordane	0/4	ND	-	10					0/4	ND	-	10				
p,p' DDT	0/4	ND	-	10					0/4	ND	-	10				
p,p' DDD	0/4	ND	-	10					0/4	ND	-	10				
p,p' DDE	0/4	ND	-	10					0/4	ND	-	10				
PCBs	0/4	ND	-	10					0/4	ND	-	10				
2,4-D	0/4	ND	-	10					0/4	ND	-	10				
2,4,5-T	0/4	ND	-	10					0/4	ND	-	10				
C_4-C_{12}*	-	-	-	-					-	-	-	-				
Benzene	0/4	ND	-	10					0/4	ND	-	10				

KEY: Column 1 = number of samples above detection limit/total number of samples analyzed.

Column 2 = range of concentrations reported (µg/l).

Column 3 = median concentration value (µg/l).

Column 4 = detection limit used (µg/l).

Priority Pollutant Organics - analysis performed by Spectrix Corporation, Houston, Texas.

ND = not detected (which means that the pollutant was found to be at a concentration level less than the detection limit).

*For C_4-C_{12} Column 1 represents: number of carbon numbers above detection limit/total number of carbon numbers analyzed.

first flush samples collected at the aforementioned sites is presented in Table 39. The complete analytical results for the analysis of the 129 priority pollutants measured in Austin NURP samples are presented in Appendix F to this report. (This appendix also includes data from the Nationwide Urban Runoff Program priority pollutant survey.)

Of the compounds in the list of priority pollutants, none of the volatile organics or base and neutral extractables were detected. Arsenic, chromium, copper, selenium, and zinc were detected in both the samples and duplicates but they were present at relatively low levels. Cyanide and phenol also were detected, but at low concentrations. Moreover, the majority of the priority pollutants present in the Austin NURP samples were at concentration levels considerably below the levels detected during the national survey.

The following can be concluded from the data on toxic organics and metals in storm water runoff samples from the Northwest Austin and Rollingwood sites:

(1) Defoliants, insecticides, PCBs, and aromatic hydrocarbons in Austin residential storm water runoff samples were usually nondetectable even at low detection limits. (As presented in Table 38, minimum detection limits of approximately 0.01 micrograms/liter for a given pollutant were obtained by multiple extractions of large sample volumes.)

(2) Organic priority pollutants were not detected in storm water runoff samples from the test watersheds.

(3) Metals were detected at relatively low concentrations (primarily lead and zinc) in storm water runoff from the test watersheds, however, their presence was not unexpected.

RECEIVING WATER

Survey Results

A receiving water quality survey conducted during the early spring (March-April) of 1981 produced background data on the ambient water quality conditions and lake sediment quality in Lake Austin and Town Lake. An additional receiving water survey was made during September, 1981 in order to obtain data on water quality and sediment conditions after the protracted rainy season which began with the Memorial Day flood. Fish samples also were

TABLE 39

PRIORITY POLLUTANTS IN AUSTIN STORM WATER RUNOFF

Detected Parameter (µg/l)	Sample Number							
	H1050 pp*	H1050 pp (duplicate)*	H1401 pp	H1401 pp (duplicate)	R1701 pp*	R1701 pp (duplicate)*	R2401 pp	R2401 pp (duplicate)
Arsenic	<ND 5**	<ND 5**	3.3	4.6	4.3	4.1	<ND 5**	<ND 5**
Chromium	<ND 20**	<ND 20**	26	26	<ND 20**	<ND 20**	<ND 20**	<ND 20**
Copper	<ND 20**	<ND 20**	25	24	12.0	12	<ND 20**	<ND 20**
Lead	60.5	54.5	126	155	140.1	138.4	37.6	38.3
Selenium	<ND 5**	<ND 5**	<ND 5**	<ND 5**	11.3	12.5	<ND 7**	<ND 7**
Zinc	29.0	38.5	99	88	64	64	10	10
Phenol	8.0	-	4.0	-	-	-	-	-
Cyanide	5.0	-	2.0	-	-	-	-	-
Methylene Chloride	ND	ND	ND	ND	452	624	269	178
4-4' DDD	ND	ND	<10	ND	ND	ND	ND	ND
4-4' DDT	ND	ND	ND	<10	ND	ND	ND	ND
Pentachlorophenol	ND	ND	ND	14	ND	ND	ND	ND
Bis(2-ethylhexyl) phthalate	ND	ND	ND	ND	ND	ND	ND	18

NOTE: If a compound is not listed, it was reported as "not detected".
H = Northwest Austin (Hart Lane) site and R = Rollingwood site.

*Indicates a "first flush" sample.

**Not detected at specified limit.

taken and analyzed for the presence of heavy metals and chlorinated hydrocarbons.

Ambient Water Quality Conditions

The results of the Town Lake-Lake Austin ambient water quality sampling survey are presented in Tables 40 and 41, respectively. In general the observed conventional water quality parameters are consistent with the levels reported in routine monitoring by the USGS and the City of Austin for the two lakes (see Tables 3 and 4). None of the currently applicable TDWR water quality standards for the segments of the Colorado River system which include Town Lake and Lake Austin, namely, TDWR water quality segments 1402 and 1403, were violated by the observed water quality conditions as represented by these data. The bacteriological quality of the lake waters was quite good, although these numbers may be biased on the low side because of large serial dilutions used during laboratory sample preparation. Analyses for heavy metals showed concentrations greater than the detection limits of the recognized analytical procedure for only zinc and arsenic. (All other metals were apparently present at trace levels.) For example, zinc was found to be detectable in quantities of .005 to .014 mg/l in Town Lake waters.

Some additional metals data collected during September, 1981 are presented in Table 42. These data indicate that arsenic, copper, zinc, cadmium, mercury and lead exist at relatively low concentrations in the waters of Lake Austin and Town Lake. (These data were analyzed at much lower detection limits than were used during the background survey analysis.) The apparent mercury levels present in the waters at stations ES-1, ES-5, and ES-6 increased slightly over that measured during the background survey. This increase is not considered significant, however, since it is within the limits of the sensitivity of the cold vapor atomic absorption method used in the analysis.

Lake Sediments

The results of sediment analyses are presented in Tables 43 and 44 for Town Lake and Lake Austin, respectively. These sediment samples provide a long-term record of environmentally-persistent constituents which have been deposited in the lakes, even though ambient concentrations in the overlying water column at any point in time may not have indicated significant levels of

TABLE 40

AMBIENT WATER QUALITY CONDITIONS IN TOWN LAKE DURING PRELIMINARY SURVEY MARCH 1981

Water Quality Parameters	Station Location		
	ES 4 Mopac Bridge	ES 5 South First Street Bridge	ES 6 Main Pool Near Longhorn Dam
Alkalinity, mg/l	138	140	144
BOD_5, mg/l	<1	<1	<1
COD, mg/l	23	11	4
Total Organic Carbon, mg/l	12.8	14.8	14.0
Total Kjeldahl Nitrogen, mg/l	1.03	0.97	0.95
Ammonia Nitrogen, mg/l	0.10	0.13	0.20
Nitrite Nitrogen, mg/l	<0.01	<0.01	<0.01
Nitrate Nitrogen, mg/l	0.26	0.32	0.35
Total Phosphorus, mg/l	0.02	0.03	0.03
Ortho-Phosphorus, mg/l	<0.01	0.01	0.01
Total Dissolved Solids, mg/l	293	337	376
Total Suspended Solids, mg/l	4	7	11
Mercury, mg/l	<0.0005	<0.0005	<0.0005
Zinc, mg/l	0.012	0.005	0.014
Cadmium, mg/l	<0.001	<0.001	<0.001
Arsenic, mg/l	<0.02	<0.02	<0.02
Copper, mg/l	<0.02	<0.02	<0.02
Lead, mg/l	<0.05	<0.05	<0.05
Fecal Coliforms*, No./100 ml	2	4	6

*Fecal coliform numbers may be biased on the low side because of large serial dilutions used during laboratory sample preparation.

TABLE 41

AMBIENT WATER QUALITY CONDITIONS IN LAKE AUSTIN DURING PRELIMINARY SURVEY MARCH 1981

Water Quality Parameters	Station Location		
	ES-1 Bull Creek Confluence	ES-2 Dry Creek Confluence	ES-3 Main Pool Near Tom Miller Dam
Alkalinity, mg/l	138	134	136
BOD_5, mg/l	<1	<1	<1
COD, mg/l	57	76	8
Total Organic Carbon, mg/l	17.2	17.9	13.5
Total Kjeldahl Nitrogen, mg/l	0.95	0.94	1.07
Ammonia Nitrogen, mg/l	<0.01	0.15	0.20
Nitrite Nitrogen, mg/l	<0.01	<0.01	<0.01
Nitrate Nitrogen, mg/l	0.28	0.26	0.27
Total Phosphorus, mg/l	0.01	<0.01	<0.01
Ortho-Phosphorus, mg/l	0.01	<0.01	<0.01
Total Dissolved Solids, mg/l	326	322	382
Total Suspended Solids, mg/l	6	14	6
Mercury, mg/l	<0.0005	<0.0005	<0.0005
Zinc, mg/l	0.007	<0.005	<0.005
Cadmium, mg/l	<0.001	<0.001	<0.001
Arsenic, mg/l	0.03	<0.02	<0.02
Copper, mg/l	<0.02	<0.02	<0.02
Lead, mg/l	<0.05	<0.05	<0.05
Fecal Coliforms,* No./100 ml	3	6	5

*Fecal coliform numbers may be biased on the low side because of large serial dilutions used during laboratory sample preparation.

TABLE 42

METALS CONCENTRATIONS IN LAKE AUSTIN AND TOWN LAKE

Station	Metals* (ppm)					
	Arsenic	Cadmium	Copper	Mercury	Lead	Zinc
Water Column						
ES-1	<0.01	<0.001	0.0024	0.0017	<0.001	<0.005
ES-2	<0.01	<0.001	0.0015	<0.0005	<0.001	<0.005
ES-3	0.047	<0.001	<0.001	<0.0005	<0.001	<0.005
ES-4	0.01	<0.001	<0.001	<0.0005	<0.001	<0.005
ES-5	<0.01	<0.001	<0.001	0.0011	0.0032	<0.005
ES-6	<0.01	<0.001	0.0026	0.0011	<0.001	<0.005
Sediments						
ES-2	-	0.054	-	<0.01	14.90	-
ES-3	-	0.045	-	<0.01	9.54	-
ES-4	-	0.212	-	<0.01	42.30	-
ES-5	-	0.019	-	<0.01	<0.10	-
ES-6	-	0.020	-	<0.01	0.40	-

*Survey conducted September 1981.

TABLE 43

ANALYSIS OF SEDIMENTS FROM TOWN LAKE
MARCH 1981

Parameter	Collection Site								
	4A	4B	4C	5A	5B	5C	6A	6B	6C
Percent Solid	61	58	54	58	62	61	72	68	66
Clay, percent	33.76	31.16	18.14	31.14	38.72	23.66	32.58	30.90	20.18
Sand, percent	16.85	20.75	24.20	5.95	21.40	12.65	11.20	28.10	17.25
Silt, percent	49.39	48.09	57.66	62.91	29.88	63.69	56.22	41.00	62.57
Volatile Fraction, mg/kg	84	101	111	81	72	82	49	58	90
Total Kjeldahl Nitrogen, mg/kg	56	4,300	4,200	2,700	2,700	2,600	1,700	1,900	2,400
Arsenic, mg/kg	5.8	12.5	17.4	0.4	5.1	11.8	11.3	10.3	9.7
Copper, mg/kg	19	17	21	26	24	27	36	35	50
Mercury*, mg/kg	0.78	0.05	1.3	0.37	0.18	0.35	0.08	1.5	0.12
Lead, mg/kg	120	49	136	123	158	109	148	150	183
Zinc, mg/kg	75	69	101	101	100	117	111	107	143
Cadmium*, mg/kg	4.1	0.08	3.7	1.9	3.2	0.9	3.3	2.6	3.1
DDE, µg/kg	24	91	92	47	56	71	46	58	5
DDD, µg/kg	5	96	97	35	31	45	35	63	5
DDT, µg/kg	5	124	92	43	37	79	13	19	5
Diazinon, mg/kg	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
2,4-D, mg/kg	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
2,4,5-T, mg/kg	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

NOTE: Stations A,B, and C represent discrete samples taken at each monitoring site.

*Additional sample surveys indicated that these metals probably exist in the sediments at much lower concentrations (see Table 42).

TABLE 44

ANALYSIS OF SEDIMENTS FROM LAKE AUSTIN
MARCH 1981

Parameter	Collection Site								
	1A	1B	1C	2A	2B	2C	3A	3B	3C
Percent Solid	70	68	63	68	63	68	64	66	61
Clay, percent	26.20	34.84	16.48	19.04	28.54	35.88	24.83	16.92	48.06
Sand, percent	14.50	5.20	25.00	8.40	1.60	14.60	7.15	20.10	22.20
Silt, percent	59.30	59.96	58.52	72.56	69.86	49.52	68.02	62.98	29.74
Volatile Fraction, g/kg	49	52	63	55	60	64	59	49	80
Total Kjeldahl Nitrogen, mg/kg	1,500	1,700	2,500	2,000	3,300	1,200	2,400	1,700	2,600
Arsenic, mg/kg	4.3	6.7	5.8	3.9	8.0	6.7	7.1	2.0	6.8
Copper, mg/kg	13	17	17	15	16	20	18	19	19
Mercury*, mg/kg	0.03	0.03	0.03	0.10	3.7	0.09	0.84	0.03	0.12
Lead, mg/kg	45	81	76	64	79	65	74	73	67
Zinc, mg/kg	30	44	36	47	49	53	50	38	55
Cadmium*, mg/kg	1.4	2.3	2.6	2.0	2.6	2.3	2.8	3.4	3.4
DDE, µg/kg	108	<5	<5	97	63	23	<5	6	<5
DDD, µg/kg	75	<5	<5	101	63	11	<5	<5	<5
DDT, µg/kg	72	<5	<5	53	39	17	<5	<5	<5
Diazinon, mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
2,4-D, mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
2,4,5-T, mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

NOTE: Stations A,B, and C represent discrete samples taken at each monitoring site.

*The magnitude of these data are unusually high and don't correspond to information presented in the report entitled "Intensive Surface Water Monitoring Survey for Segment No. 1403, Lake Austin" TDWR, June 1976. Additional sample surveys indicated that these metals probably exist in the sediments at much lower concentrations (see Table 42).

the pollutant. The sediment record also provides the best opportunity for documenting historical pollutant discharges or releases of persistent compounds, such as pesticides, herbicides, and heavy metals. Moreover, the observed concentrations provide a means for assessing the potential environmental effects of those substances.

Lead and zinc concentrations in the lake sediments were significantly higher at Town Lake stations than at Lake Austin sites, with observed levels highest near Longhorn Dam. Copper concentrations were slightly higher in Town Lake when data from the two lakes are compared. Mercury and cadmium levels also appear slightly higher in Town Lake, but the observed concentrations are somewhat erratic for certain sediment samples and these data preclude a definitive interpretation.

As more data were obtained after the period of excessive rainfall, the apparent distribution of metals in the lake sediments seemed to be altered by the probable dispersion of the lake bottoms during the Memorial Day flood (see Table 42). Mercury and cadmium levels in the lake sediments appear to be much lower than that measured during the background survey. Moreover, the distribution of lead in the sediments of Lake Austin and Town Lake are quite different from that reported during the early spring survey. This apparent anomaly in the data base only serves to emphasize the need for additional survey data. The sediment quality distribution in the lakes can be better defined by obtaining data from sediment cores. Such a sampling survey would provide information relative to the historical distribution of metals and toxic organics in the two lakes. These data would permit a proper assessment of the distribution of pollutants in the sediments of Town Lake and Lake Austin. Until such data are obtained, a definitive assessment of the impact associated with the presence of pollutants in the sediments of Town Lake and Lake Austin is premature.

Potentially toxic organics, such as diazinon, 2,4-D and 2,4,5-T are in the water column but did not appear to be accumulating in either of the lake sediments. None of these compounds were detected in concentrations above 0.1 mg/kg of sediment (dry weight). DDT and its breakdown intermediates (DDE, DDD) were detected at concentrations up to 124 μg/kg of sediment (dry weight) in Town Lake. Observed levels in Town Lake were generally higher than those for Lake Austin, although the upper ends of Bull Creek and Dry Creek (tributaries to Lake Austin) had levels comparable to Town Lake samples. Residues of these persistent compounds were lowest in the main pool of Lake Austin near the dam.

Fish Tissue Analysis

Although the dynamics of environmental contamination involves the interaction between the abiotic and biotic components of the ecosystem, the pathways of this contamination in the two components are different. The contaminants in the abiotic environment are usually subject to dispersion, transformation, and decay which result in a dilution of the overall contamination levels, whereas plants and animals of the biotic part tend to involve the accumulation of contaminants which may result in a magnification of pollutants in the biological units (both animals and plants). In aquatic environments, fish may be considered the important biological indicators of the system because they are highest in the trophic level and have relatively long life spans, diversified habitats, and feeding habits. This combination of factors permits close contact with the various types of pollutants that may be present in the water, sediments, and other aquatic plants and organisms.

According to the Texas Parks and Wildlife Department, Lake Austin and Town Lake are known to support large populations of a variety of native sport fish and non-native introductions such as largemouth bass, spotted bass, northern pikes, and various species of sunfish. However, the Texas Parks and Wildlife Department feels that the fishery resources in both reservoirs are under utilized, and that sport fishing should be stimulated. Since fishery information plays an important part in increasing the utilization of the resources of the reservoirs that receive various pollutants from recreational activities and storm runoff, an investigation into the existing quality of edible fish was thought necessary for public health protection before a recommendation of more sport fishing could be declared.

Because a variety of pollutants reach the lake receiving waters and sediments through various pathways, the Austin NURP study selected six metals and two persistent chlorinated hydrocarbons for the fish tissue analysis. Arsenic, cadmium, copper, mercury, lead, and zinc were the metals selected due to their presence in lake waters and storm runoff. DDT and its breakdown products, DDD and DDE, were selected with PCBs as the chlorinated hydrocarbon candidates because they were known to have been released in the reservoirs in the past and also because of their conservative chemical properties. Therefore, a total of 20 adult fish, 10 from Town Lake and 10 from Lake Austin were collected during September of 1981 and these samples were used to establish information on the background conditions in the lakes. Chlorinated hydrocarbon residues present in fish tissue were determined by a gas chromatography procedure which utilized liquid-liquid extraction techniques and the metal levels were detected by atomic absorption spectrophotometry. Both methods were approved by the EPA.

The bluegill sunfish, redear sunfish, redbreasted sunfish, Rio Grande perch, and largemouth bass comprise the fish samples taken from Town Lake, whereas the bluegill sunfish, redear sunfish, and longnose gar comprise the Lake Austin fish samples. Except for the Rio Grande perch which is an omnivorous fish feeding on both plants and animals, the other adult fish are carnivorous and feed primarily on insect larvae, small crustacean, macroinvertebrates, and smaller fish.

Chlorinated Hydrocarbons

The chlorinated hydrocarbon residues present in both the biotic and abiotic components of the ecosystem have been a matter of some concern in the aquatic environment since the realization that these materials bioconcentrate in aquatic animals. The long half life and conservative chemical properties of these substances make their residue distributions in the environment extensive, especially in the sediments that act as reservoirs for the accumulation of these pollutants. Light textured sediment particles such as sand and sandy loam provide relative ease of movement for water and thus pollutants, whereas heavier textured particles such as clay soils adsorb the soluble pollutants and attract the more insoluble pollutants. Once a pollutant reaches the sediment, it is subject to decay, adsorption on particles in deeper layers of sediments, transfer to other locations, or transfer to living tissues of plants and animals. Because the industrial chemical, PCB, and the insecticide, DDT, are neurotoxic to aquatic life and residues in the lake sediments are within detectable levels; the tendency for accumulation in aquatic organisms that live in the lakes should be given special attention.

PCBs or polychlorinated biphenyls are a mixture of synthetic organic compounds containing varying amounts of chlorine. They are mostly insoluble in water but are soluble in oils and fats and are resistant to degradation by heat, acids, alkalis, and biological organisms. They tend to accumulate in the adipose (fatty) tissue of organisms, and a number of aquatic organisms have been observed to concentrate PCBs in their tissue from 3,000 to 200,000 times. However, the data collected during the Austin NURP study show that all fish samples taken from both lakes contain less than 100 ppb of PCBs in their tissues (see Tables 45 and 46). The U.S. Food and Drug Administration has set a standard for PCBs in edible fish at 5,000 ppb to protect consumers. The fish collected from Town Lake and Lake Austin have PCB levels in their tissues which are well below this maximum allowable level.

DDT also is a major concern for the lake sport fishery. DDT is a chlorinated hydrocarbon compound formerly used as a pesticide. Because it was one of the first pesticides produced, its use was widespread, consequently, the residues of this compound pose a persistent problem. Similar to PCBs, this compound is almost insoluble in water and has a half life of 12 to 17 years. DDT also breaks down to DDD and DDE, two compounds with similar molecular structures and chemical properties. DDD, a metabolite of DDT, also was manufactured as a pesticide. DDE is the major and final breakdown product of DDT with a half life in excess of 10 years and is the most widely distributed pesticide residue in Lake Austin and Town Lake. However, DDT and its breakdown products behave in a similar manner in that they are almost insoluble in water and are not decomposed by sunlight. These chlorinated pesticides are extremely stable in sediments, adhering to sediment particles, and degrading at a rate of about five percent per year. DDT and its breakdown products are carcinogenic to living organisms and possibly man. Under several experimental conditions, DDT has induced liver tumors in mice (Innes, et al., J. Natl. Cancer Inst. 42:1101-14, 1969). They are lipophilic (preferring fat) in nature and are bioaccumulated upward through the food chain with little being lost due to excretion.

According to the fish data shown in Tables 45 and 46, the sum of the residue DDT components (DDD + DDE + DDT) range in concentration between 141 ppb and 5,890 ppb. Lake Austin fish, however, tend to contain less residue complex than Town Lake fish. Lake Austin fish data show a lower concentration

TABLE 45

ANALYSIS OF TOXIC ORGANICS IN FISH TISSUE FROM TOWN LAKE
SEPTEMBER 1981

Species Common Name: Scientific Name	Weight (g)	Tail Length (cm)	Organics (μg/kg) in Tissue			
			DDD	DDE	DDT	PCBs
Rio Grande Perch #1[3]: *Cichlasoma cyanoguttatum*	173	19.1	380	880	260	<100
Rio Grande Perch #2[3]:	172	19.1	1,500[4]	3,600[4]	790[4]	<100
Redbreasted Sunfish #1[1]: *Lepomis auritus*	236	20.7	160	670	380	<100
Redbreasted Sunfish #2[1]:	194	20.3	140	1,500	46	<100
Redbreasted Sunfish #3[2]:	91	17.2	350	1,400	290	<100
Bluegill Sunfish #1[2]: *Lepomis macrochirus*	165	-[5]	100	380	150	<100
Bluegill Sunfish #2[3]:	94	15.9	79	490	79	<100
Redear Sunfish #1[3]: *Lepomis microlophus*	150	20.3	40	380	150	<100
Redear Sunfish #2[3]:	150	19.7	160	560	60	<100
Largemouth Bass: *Micropterus salmoides*	428	31.8	40	370	40	<100

[1] ES-4 site.

[2] ES-5 site.

[3] ES-6 site.

[4] Sum of the DDT residue concentrations exceed the U.S. Food and Drug Administration cumulative standard of 5,000 μg/kg.

[5] Composite sample of several fish approximately 5 cm in length used in analysis.

TABLE 46

ANALYSIS OF TOXIC ORGANICS IN FISH TISSUE FROM LAKE AUSTIN
SEPTEMBER 1981

Species Common Name: Scientific Name	Weight (g)	Tail Length (cm)	Organics (µg/kg) in Tissue			
			DDD	DDE	DDT	PCBs
Bluegill Sunfish #3[2]: Lepomis macrochirus	86	16.5	27	250	10	<100
Bluegill Sunfish #4[2]:	66	14.6	20	180	<10	<100
Bluegill Sunfish #5[3]:	102	17.2	73	380	120	<100
Redear Sunfish #3[1]: Lepomis microlophus	160	20.3	280	870	200	<100
Redear Sunfish #4[1]:	185	23.5	24	87	30	<100
Redear Sunfish #5[2]:	76	15.9	85	230	10	<100
Redear Sunfish #6[2]:	59	15.3	20	120	<10	<100
Redear Sunfish #7[3]:	55	15.3	19	84	38	<100
Longnose Gar #1[2]: Lepisosteus osseus	398	58.4	310	2,700	200	<100
Longnose Gar #2[2]:	295	58.4	40	560	<10	<100

[1] Fish taken from ES-1 site.

[2] Fish taken from ES-2 site.

[3] Fish taken from ES-3 site.

range of DDT components at cumulative levels between 141 ppb and 3,210 ppb, where the maximum concentration was found in samples taken from the longnose gar; the highest predatory fish in the sample catch. Moreover, all of the fish taken from Lake Austin have a concentration level in their tissue of DDT and its breakdown products which is less than the standard of 5,000 ppb set by the U.S. Food and Drug Administration in order to protect public health. Fish taken from Town Lake, on the other hand, show higher DDT complex levels with a range between 450 ppb and 5,890 ppb. Although the maximum DDT complex level exceeds the U.S. Food and Drug Administration standard, only one fish sample (Rio Grande perch) of the 10 collected in Town Lake had a measured value greater than 5,000 ppb. Since this level was detected in the tissue of a Rio Grande perch, the data suggest that the fish feeding habits play an important role in pesticide residue transfer from sediments to organisms. The Rio Grande perch is an omnivorous fish and tends to feed on both plants and small organisms. The vascular plants are known to be able to accumulate some pesticides from deeper layers of the sediments and the green algae can accumulate pesticides at a rather rapid rate, therefore, these aquatic plants may be the major contributor of DDT to the perch.

The data also show that all fish contain higher levels of DDE in their tissues than DDD and DDT. This pattern is common of the likely distribution of DDT in the aquatic environment. Given the higher DDE levels recorded from an analysis of the tissues from all the sample fish, it can be assumed that the DDT residues present in these organisms may be in its final state of degradation. Fifty percent of the fish taken from Lake Austin also show DDT residue levels of 10 ppb or less. Town Lake fish appear to contain DDT residue in a higher quantity than Lake Austin, and this is probably due to a more intense use of the insecticide along the shoreline in the past.

Metals

In the metals analysis, the data indicate that the metals are distributed among all fish species at random as shown in Tables 47 and 48 for Town Lake and Lake Austin, respectively. Except for copper and lead, fish samples taken from Lake Austin appear to contain slightly higher concentrations of the metals in their tissue than fish collected from Town Lake.

TABLE 47

ANALYSIS OF METALS IN FISH TISSUE FROM TOWN LAKE
SEPTEMBER 1981

Species Common Name: Scientific Name	Metals (μg/kg) in Tissue					
	As	Cd	Cu	Hg	Pb	Zn*
Rio Grande Perch #1[3]:*Cichlasoma cyanoguttatum*	40	2.0	55	<17	500	9.9
Rio Grande Perch #2[3]:	60	2.5	75	<17	<50	9.1
Redbreasted Sunfish #1[1]:*Lepomis auritus*	60	<0.5	1,400	<17	<50	12.0
Redbreasted Sunfish #2[1]:	105	<0.5	960	<17	<50	21.0
Redbreasted Sunfish #3[2]:	25	<0.5	1,200	<17	200	13.0
Bluegill Sunfish #1[2]:*Lepomis macrochirus*	<20	<0.5	1,800	<17	<50	14.0
Bluegill Sunfish #2[3]:	<20	<0.5	14	<17	<50	7.5
Redear Sunfish #1[3]:*Lepomis microlophus*	55	<0.5	56	<17	<50	14.0
Redear Sunfish #2[3]:	45	<0.5	1,100	<17	<50	20.0
Largemouth Bass: *Micropterus salmoides*	<20	<0.5	40	<17	<50	9.9

*Concentration in mg/kg.

[1] ES-4 site.

[2] ES-5 site.

[3] ES-6 site.

TABLE 48

ANALYSIS OF METALS IN FISH TISSUE FROM LAKE AUSTIN
SEPTEMBER 1981

Species Common Name: Scientific Name	Metals (µg/kg) in Tissue					
	As	Cd	Cu	Hg	Pb	Zn*
Bluegill Sunfish #3[2]: *Lepomis macrochirus*	<20	6.0	740	<17	<50	7.9
Bluegill Sunfish #4[2]:	30	<0.5	95	38	<50	1.7
Bluegill Sunfish #5[3]:	83	<0.5	60	<17	<50	14.0
Redear Sunfish #3[1]: *Lepomis microlophus*	40	<0.5	110	<17	<50	16.0
Redear Sunfish #4[1]:	35	<0.5	50	<17	<50	25.0
Redear Sunfish #5[2]:	30	<0.5	25	<17	<50	26.0
Redear Sunfish #6[2]:	185	13.0	1,200	<17	<50	14.0
Redear Sunfish #7[3]:	65	<0.5	25	30	<50	20.0
Longnose Gar #1 : *Lepisosteus osseus*	<20	4.5	1,500	<17	<50	7.8
Longnose Gar #2:	20	<0.5	85	<17	<50	10.0

[1] Fish taken from ES-1 site.

[2] Fish taken from ES-2 site.

[3] Fish taken from ES-3 site.

*Concentration in mg/kg.

Arsenic levels range from less than 20 ppb through 185 ppb with the maximum value reported in the tissues of Lake Austin redear sunfish. The concentration range for cadmium was from less than 0.5 ppb through 13.0 ppb, again, the maximum value was found in tissues from Lake Austin redear sunfish. However, 80 percent of the fish from Town Lake and 70 percent of the fish from Lake Austin contained cadmium levels that were less than 0.5 ppb. Mercury levels ranged from less than 17 ppb through 38 ppb, and again the maximum concentration was detected in the tissue from a Lake Austin bluegill sunfish. All of the fish collected from Town Lake and 80 percent of the Lake Austin fish contained mercury concentrations less than 17 ppb. Zinc concentrations measured in the tissues of the fish samples collected in the two lakes ranged from 1.7 ppm through 26.0 ppm, and the maximum value was obtained from the tissue of a Lake Austin redear sunfish.

Copper levels ranged from 14 ppb through 1,800 ppb with the maximum concentration detected in the tissues from a Town Lake bluegill sunfish. However, 40 percent of the fish taken from Town Lake and 20 percent of the fish taken from Lake Austin had copper levels greater than 1,000 ppb in their tissue. The concentrations of lead ranged from less than 50 ppb through 500 ppb, and the maximum concentration was obtained from a Town Lake Rio Grande perch. All of the fish from Lake Austin and 80 percent of the fish from Town Lake contained less than 50 ppb of lead in their tissue.

Although the sediment quality data obtained during the early spring survey on Lake Austin and Town Lake indicated rather high metals concentrations (see Tables 43 and 44), metals data from 20 adult fish collected in the two lakes show no direct correlation with these high sediment concentrations. These fish data indicate that background levels of toxic metals in fish are relatively low, and that the biological transfer rates associated with the bioaccumulation of these materials are slow. However, insufficient data are available with which to assess the equilibrium levels of any of these metals in fish tissue. A more in-depth analysis of the toxic pollutant (both metals and pesticides) exposure levels associated with the various species of fish in the two lakes is required. Such a study would involve both additional surveys and exposure analysis modeling in order to describe the chemical, physical, and biological reactions which a pollutant can undergo once it reaches the receiving water.

Storm Event Monitoring in the Receiving Water Bodies

If the ambient levels of toxic materials found in the receiving waters are not sufficient to warrant concern on a long-term basis in areas known to receive substantial inputs of storm water drainage, then the monitoring of the limnological impacts associated with specific rainfall events would provide valuable information regarding the environmental effect of the conventional pollutant component of runoff. Such event-oriented activities on the lakes were conducted during the study, and these sampling activities focused on the short-term effects associated with the conventional runoff pollutants (i.e., suspended solids, fecal coliforms, oil and grease, etc.). Instead of representing a chronic health threat to humans or impacting upon the aquatic biota (in the long run), these conventional pollutants can produce transient impacts on local aquatic life and such secondary environmental impacts as increasing the treatment cost of drinking water or slightly altering the aesthetic desirability of a recreational water body.

Several receiving water surveys were conducted during the Austin NURP study which coincided with storm runoff events. The succeeding discussion will address the results of the five storm event surveys conducted in the receiving water bodies, namely, Events 13, 14, 15, 23, and 25. General water quality profile data on temperature, dissolved oxygen, transparency, and conductivity taken on the lakes during all storm runoff periods are shown in Appendix G to this report.

Storm Event 13 (5/1/81)

During mid-morning of May 1, 1981, a heavy thunderstorm moved through the study area, and sampling activities were initiated on Lake Austin that afternoon. Light, but continuous showers fell the next day, and sampling resumed on May 3 to monitor the cumulative effect of these storms. The sampling stations during this event survey were located at: (1) Lake Austin - near Loop 360 bridge; (2) Bull Creek - three sites; (3) Dry Creek - three sites; and (4) Lake Austin - main pool near Tom Miller Dam.

The observed conditions in the upper ends of the Lake Austin tributaries (Bull and Dry Creeks) did exhibit some changes in selected water quality parameters due to the two runoff episodes associated with this storm, and these data are indicated in Table 49. In Bull and Dry Creeks, levels of TSS

TABLE 49

WATER QUALITY CONDITIONS IN LAKE AUSTIN
AFTER STORM EVENT 13 (5/01/81)

Sampling Date	Parameter	Station ES-0-0	ES-1-A	ES-1-B	ES-1-C	ES-2-A	ES-2-B	ES-2-C	ES-3
5-1-81	Alkalinity (mg/l)	134	148	134	134	136	136	140	138
	BOD$_5$ (mg/l)	7	7	6	7	8	7	7	7
	COD (mg/l)	11	15	15	8	11	11	8	8
	TOC (mg/l)	5.0	7.2	5.8	7.0	9.4	2.1	4.0	6.3
	Nitrogen, ammonia (mg/l)	0.27	0.27	0.24	0.27	0.80*	0.67*	0.21	0.19
	Nitrogen, nitrate (mg/l)	0.34	0.56	0.32	0.28	0.78	0.19	0.26	0.35
	Nitrogen, nitrite (mg/l)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Nitrogen, total (mg/l)	0.71	0.78	0.85	0.61	1.92	5.37	0.61	0.62
	Ortho-phosphorus, Diss. (mg/l)	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03
	Phosphorus, Total (mg/l)	0.03	0.09	0.03	0.03	0.17	0.03	0.03	0.03
	Solids, Total Diss. (mg/l)	286	350	321	323	329	322	312	313
	Solids, Total Susp. (mg/l)	5	69	14	5	144	14	7	6
	Fecal Coliform** (No./100 ml)	100	400	100	100	1,000	100	100	100
5-3-81	Alkalinity (mg/l)	140	188	146	144	144	144	140	138
	BOD$_5$ (mg/l)	8	7	8	6	8	8	7	8
	COD (mg/l)	8	8	8	8	15	5	8	8
	TOC (mg/l)	14.0	6.6	3.2	3.1	14.6	13.0	15.7	15.4
	Nitrogen, ammonia (mg/l)	0.80*	0.38	0.33	0.17	0.43	0.73*	0.71*	0.80*
	Nitrogen, nitrate (mg/l)	0.33	0.34	0.26	0.27	0.52	0.26	0.22	0.30
	Nitrogen, nitrite (mg/l)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Nitrogen, total (mg/l)	1.08	0.63	0.61	0.62	0.89	4.63	3.00	1.47
	Ortho-phosphorus, Diss. (mg/l)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Phosphorus, Total (mg/l)	0.01	0.03	0.03	0.03	0.06	0.03	0.01	0.01
	Solids, Total Diss. (mg/l)	293	330	333	309	281	283	303	299
	Solids, Total Susp. (mg/l)	7	38	19	4	39	17	8	5
	Fecal Coliform** (No./100 ml)	100	100	100	100	300	100	100	100
5-4-81	Alkalinity (mg/l)	140	178	150	142	158	140	142	144
	BOD$_5$ (mg/l)	7	9	7	6	8	8	7	8
	COD (mg/l)	27	19	11	19	19	19	30	19
	TOC (mg/l)	15.1	14.6	15.8	14.3	13.5	14.5	15.5	14.2
	Nitrogen, ammonia (mg/l)	0.25	1.04*	0.35	0.91*	0.57*	0.27	0.27	0.48
	Nitrogen, nitrate (mg/l)	0.33	0.33	0.26	0.31	0.35	0.28	0.26	0.35
	Nitrogen, nitrite (mg/l)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Nitrogen, total (mg/l)	0.70	1.93	0.77	1.82	0.76	0.73	0.74	0.82
	Ortho-phosphorus, Diss. (mg/l)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Phosphorus, Total (mg/l)	0.03	0.05	0.03	0.03	0.07	0.03	0.03	0.03
	Solids, Total Diss. (mg/l)	314	388	268	252	179	226	279	316
	Solids, Total Susp. (mg/l)	1	29	13	7	129	22	5	3
	Fecal Coliform** (No./100 ml)	100	100	100	100	100	100	100	100
5-5-81	Alkalinity (mg/l)	138	172	150	144	148	142	138	149
	BOD$_5$ (mg/l)	5	7	8	7	8	8	5	7
	COD (mg/l)	19	23	27	8	19	19	38	30
	TOC (mg/l)	6.2	7.5	8.9	5.7	13.8	13.6	17.0	16.1
	Nitrogen, ammonia (mg/l)	0.35	0.51*	0.67*	0.39	0.53*	0.73*	0.65*	0.51*
	Nitrogen, nitrate (mg/l)	0.34	0.26	0.35	0.30	0.35	0.34	0.27	0.28
	Nitrogen, nitrite (mg/l)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Nitrogen, total (mg/l)	0.59	0.68	0.67	0.44	0.62	0.91	0.83	0.61
	Ortho-phosphorus, Diss. (mg/l)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Phosphorus, Total (mg/l)	0.03	0.06	0.01	0.01	0.01	0.06	0.01	0.01
	Solids, Total Diss. (mg/l)	224	293	351	238	381	347	320	360
	Solids, Total Susp. (mg/l)	1	31	17	5	27	16	4	3
	Fecal Coliform** (No./100 ml)	0	0	0	0	0	0	0	0

*Value exceeded the limitation of 0.5 mg/l.

**Some of the fecal coliform numbers are suspect because of large serial dilutions used during laboratory sample preparation.

were substantially elevated with the maximum values of 69 mg/l detected at Bull Creek and 144 mg/l at Dry Creek on the same day of the storm (see Figure 42). Runoff also increased the numbers of fecal coliforms in both creeks, especially in the back waters. A fecal coliform concentration of 400/100 ml was found at Station ES-1-A on Bull Creek, whereas a concentration of 1,000/100 ml was detected in the waters at Station ES-2-A on Dry Creek. Generally, The fecal coliform numbers which characterize the receiving water survey data for Storm Events 13 and 14 probably are biased on the low side because of problems with the serial dilution procedures used by the laboratory. The data collected thereafter are thought to be accurate reflections of the fecal coliform levels in the lakes during a storm event. An increase in ammonia concentrations was noted from all sampling stations with the maximum numbers of 1.04 mg/l found in the waters at Bull Creek Station ES-1-A and 0.91 mg/l at Dry Creek station ES-2-A. However, the data showed that ammonia concentrations rose above the acceptable water quality limit of 0.5 mg/l at various stations throughout the sampling period (see Table 50), and more than 44 percent of the samples contained ammonia concentrations which exceeded the recommended limit. Nitrate and Total phosphorus concentrations also were increased at various stations. Elevated nitrate levels were noted at Stations ES-1-A and ES-2-A on May 1, 1981, whereas elevated total phosphorus levels were noted at various stations at different times with the maximum concentration of 0.17 mg/l detected in the waters at Station ES-2-A.

A small change in concentration for a number of water quality parameters, particularly total dissolved solids and the various species of the primary nutrients (carbon, nitrogen, and phosphorus) was observed when sampling the Lake Austin stations upstream of Bull Creek (Station ES-0-0) as compared to stations in the main conservation pool near the dam (downstream of tributary inputs). It should be emphasized that tributary storm water inputs on Lake Austin, especially from urbanized areas, should be observable at the station nearest the dam, while the upstream station should reflect the water quality of Lake Travis hypolimnetic releases and small runoff inputs from predominantly rural catchments.

The data also indicated an increase in alkalinity during the sampling period. Station ES-1-A showed an increase in alkalinity right after the storm runoff event on May 1, 1981, whereas all other sampling stations showed

LAKE AUSTIN TSS AFTER STORM EVENT 13

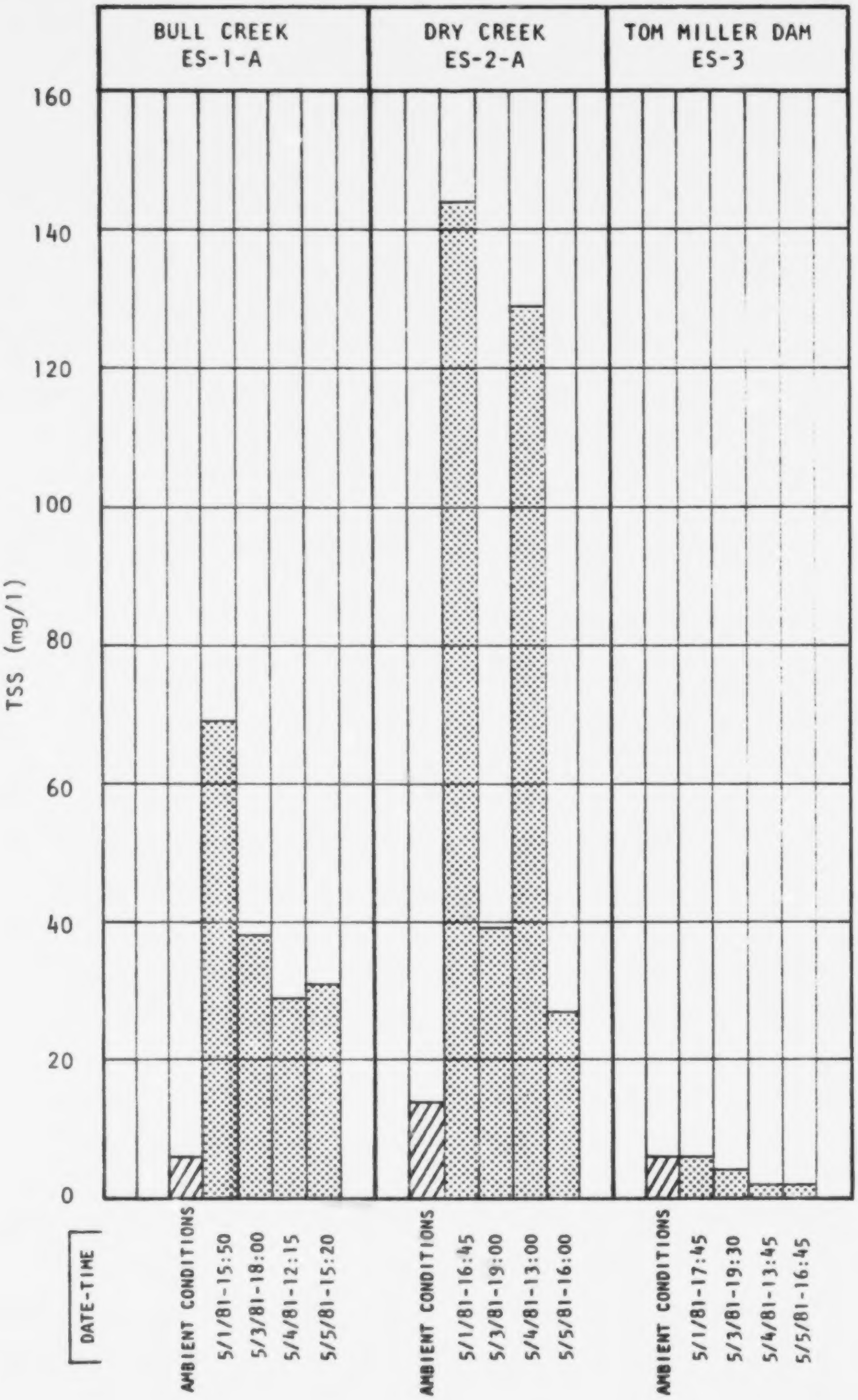


TABLE 50

AMMONIA CONCENTRATIONS AFTER STORM EVENT 13 IN LAKE AUSTIN

Date	Concentration >0.5 mg/1				Concentration < 0.5 mg/1	
	Station	Concentration >0.75	Station	Concentration >0.5	Station	Concentration >0.2
5-1-81	ES-2-A	0.80	ES-2-B	0.67	ES-0-0	
					ES-1-A	0.27
					ES-1-C	
					ES-1-B	0.24
					ES-2-C	0.21
					ES-3	0.19
5-3-81	ES-0-0	0.80	ES-2-B	0.73	ES-2-A	0.43
	ES-3		ES-2-C	0.71	ES-1-A	0.38
					ES-1-B	0.33
					ES-1-C	0.17
5-4-81	ES-1-A	1.04	ES-2-A	0.57	ES-3	0.48
	ES-1-C	0.91			ES-1-B	0.35
					ES-2-B	0.27
					ES-2-C	
					ES-0-0	0.25
5-5-81			ES-2-B	0.73	ES-1-C	0.39
			ES-1-B	0.67	ES-0-0	0.35
			ES-2-A	0.53		
			ES-1-A	0.51		
			ES-3			

elevated levels of alkalinity on May 2, 1981. These elevated alkalinity levels remained throughout the sampling period (see Figure 43).

Storm Event 14 (5/16/81)

An intense thunderstorm moved into the Austin area during the early morning hours of May 16, pouring 1.24 inches of rain on the city (as reported by the U.S. Weather Service rain gauge). Sampling of the same Lake Austin stations as during Storm Event 13 was initiated during the afternoon of May 16, and subsequent lake surveys were conducted on May 17, 18, and 20. The runoff peak exhibited with this storm was much more distinct in both intensity and associated water quality impacts on the lake waters than the previous storm event investigated as is indicated by the data presented in Table 51.

In Bull Creek, the storm water runoff resulted in increased concentrations of a wide variety of water quality constituents. Similar to Storm Event 13, Station ES-1-A showed a pronounced alkalinity increase with the maximum value of 188 mg/l on May 17, 1981. Ammonia concentrations also were elevated with a high of 1.25 mg/l in the waters at Bull Creek Station ES-1-A and 1.59 mg/l at Dry Creek Station ES-2-B on May 16, 1981. These concentrations dropped rather rapidly, however, on May 17, 1981 (see Table 51). Approximately 66 percent of the survey samples contained ammonia concentrations greater than 0.5 mg/l. In general, elevated levels of alkalinity, total organic carbon, BOD, COD, total nitrogen, ammonia, nitrate, orthophosphate, total phosphate, total suspended solids, and fecal coliforms were present in the lake waters for the first three days, then a noticeable decline toward baseline levels was observed. The change in ambient water quality conditions appeared to be due to the subsequent clearing of the waters in the uppermost tributaries to the lake as the original turbid storm water runoff inflows were displaced by seepage waters of good quality. Dissolved oxygen levels of less than five mg/l were observed during the late afternoon, along with high water temperatures, perhaps indicative of active biological decomposition of oxygen-demanding pollutants. The zone of low dissolved oxygen water was limited to the warm shallow waters of the upper end of Bull Creek while higher dissolved oxygen levels were noticed in depth profiles taken at stations closer to the lake proper (see Appendix G).

Similar water quality data were documented in the upper end of Dry Creek after the runoff episode. Increasing fecal coliform numbers were noted at

LAKE AUSTIN ALKALINITY DISTRIBUTION AFTER STORM EVENT 13

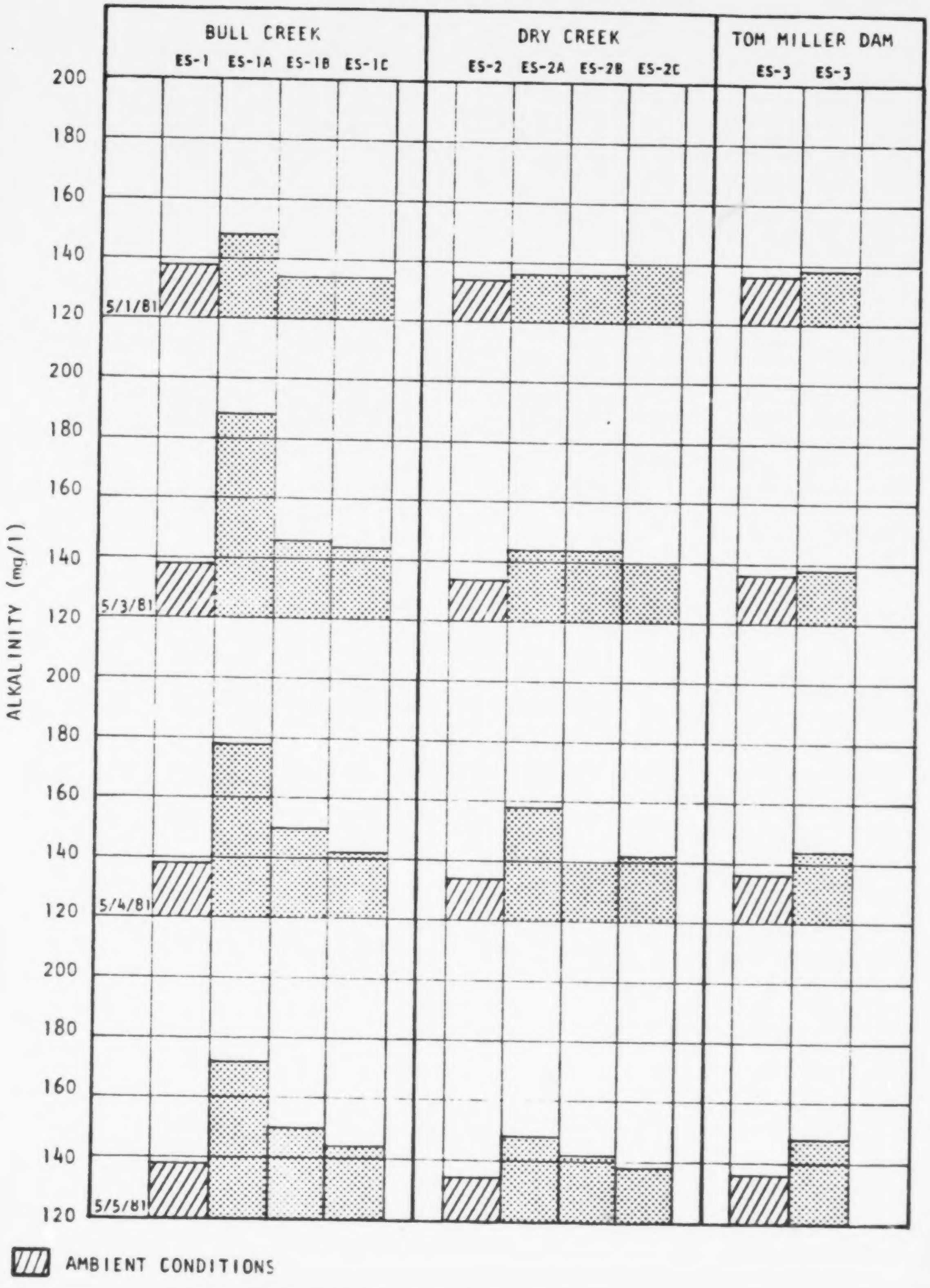


TABLE 51

WATER QUALITY CONDITIONS IN LAKE AUSTIN
AFTER STORM EVENT 14 (5/16/81)

Sampling Date	Parameter	ES-0-0	ES-1-A	ES-1-B	ES-1-C	ES-2-A	ES-2-B	ES-2-C	ES-3
		Station							
5-16-81	Alkalinity (mg/l)	144	144	158	152	146	138	132	144
	BOD$_5$ (mg/l)	1	2	16	2	16	19	10	9
	COD (mg/l)	4	4	267	4	49	65	38	23
	TOC (mg/l)	6.6	10.8	22.9	6.6	4.9	8.0	9.6	5.3
	Nitrogen, ammonia (mg/l)	0.73*	1.25*	1.53*	0.53*	0.40	1.59*	0.58*	1.00*
	Nitrogen, nitrate (mg/l)	0.50	0.64	0.01	0.10	0.11	0.46	0.17	0.18
	Nitrogen, nitrite (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Nitrogen, total (mg/l)	1.10	3.10	1.64	1.42	1.24	2.06	1.22	1.12
	Ortho-phosphorus, Total (mg/l)	<0.01	0.02	0.03	0.01	0.02	0.02	0.03	0.02
	Phosphorus, Total (mg/l)	<0.01	0.09	0.12	0.01	0.06	0.11	0.03	0.02
	Solids, Total Diss. (mg/l)	318	179	335	309	358	276	339	440
	Solids, Total Susp. (mg/l)	1	144	28	40	270	116	17	7
	Fecal Coliform** (No./100 ml)	4	19	0	0	60	153	10	3
5-17-81	Alkalinity (mg/l)	144	188	152	148	149	138	140	140
	BOD$_5$ (mg/l)	1	1	6	1	14	119	140	140
	COD (mg/l)	4	4	8	4	46	114	4	34
	TOC (mg/l)	7.5	6.8	9.6	7.2	5.7	7.9	8.5	5.9
	Nitrogen, ammonia (mg/l)	0.47	0.69*	0.53*	0.45	0.59*	0.71*	0.37	0.87
	Nitrogen, nitrate (mg/l)	0.29	0.48	0.09	0.28	0.36	0.21	0.03	0.25
	Nitrogen, nitrite (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Nitrogen, total (mg/l)	1.03	1.41	1.43	1.69	1.56	1.30	1.56	1.37
	Ortho-phosphorus, Total (mg/l)	<0.01	0.03	0.03	0.03	0.03	0.02	0.02	<0.01
	Phosphorus, Total (mg/l)	<0.01	0.06	0.09	0.05	0.07	0.03	0.14	<0.01
	Solids, Total Diss. (mg/l)	298	475	322	303	337	345	336	461
	Solids, Total Susp. (mg/l)	7	124	26	21	87	32	8	6
	Fecal Coliform** (No./100 ml)	5	4	1	1	61	183	1	3
5-18-81	Alkalinity (mg/l)	146	186	150	152	142	146	136	144
	BOD$_5$ (mg/l)	2	1	4	4	2	1	1	1
	COD (mg/l)	8	19	23	8	4	6	8	4
	TOC (mg/l)	14.1	16.3	13.0	14.4	4.1	5.8	5.2	4.3
	Nitrogen, ammonia (mg/l)	0.47	0.67*	0.75*	0.45	0.91*	0.53*	0.68*	0.49
	Nitrogen, nitrate (mg/l)	0.10	0.50	0.38	0.27	0.12	0.38	0.05	0.10
	Nitrogen, nitrite (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Nitrogen, total (mg/l)	0.97	1.10	1.15	1.03	1.24	1.08	1.16	1.01
	Ortho-phosphorus, Total (mg/l)	0.01	<0.01	<0.01	<0.01	0.03	0.05	0.01	0.01
	Phosphorus, Total (mg/l)	0.02	0.05	0.03	0.07	0.05	0.06	0.03	0.03
	Solids, Total Diss. (mg/l)	302	394	304	295	295	328	312	301
	Solids, Total Susp. (mg/l)	2	38	20	13	29	16	8	4
	Fecal Coliform** (No./100 ml)	0	0	0	3	11	29	13	3
5-20-81	Alkalinity (mg/l)	134	152	148	148	156	142	138	126
	BOD$_5$ (mg/l)	6	1	7	11	1	10	4	1
	COD (mg/l)	19	15	30	46	4	38	38	4
	TOC (mg/l)	6.0	4.0	6.3	6.4	3.9	4.2	5.2	2.2
	Nitrogen, ammonia (mg/l)	0.62*	0.32	0.41	0.42	0.57*	0.59*	0.57*	0.33
	Nitrogen, nitrate (mg/l)	0.27	0.48	0.49	0.27	0.30	0.19	0.23	0.30
	Nitrogen, nitrite (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Nitrogen, total (mg/l)	0.67	0.85	0.76	0.74	0.92	0.70	0.73	0.66
	Ortho-phosphorus, Total (mg/l)	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Phosphorus, Total (mg/l)	0.01	0.03	0.03	0.02	0.04	0.04	0.02	0.02
	Solids, Total Diss. (mg/l)	373	363	341	340	354	260	309	309
	Solids, Total Susp. (mg/l)	3	48	30	8	56	76	9	7
	Fecal Coliform** (No./100 ml)	0	16	1	0	53	4	0	0

*Value exceeded the allowable limitation of 0.5 mg/l.

Station ES-2-A throughout the sampling period. Station ES-2-B also showed more concentrated fecal coliforms in the water column during May 16, 1981 through May 18, 1981, although the concentration dropped to normal on May 20, 1981. However, the highest fecal coliform number for the entire study area was detected at Station ES-2-B which documented a level of 183 per 100 milliliters. Two days after the runoff inflows had ended, warm temperatures and stagnant conditions combined to produce ambient dissolved oxygen levels below five mg/l in the shallow backwaters of the Dry Creek arm. Such conditions were not widespread within the tributary arm, however, and dissipated within a few days. Elevated concentrations were observed for the aforementioned water quality constituents monitored (total dissolved solids included) in upper Bull Creek. Most of the observed concentrations, however, decreased over the course of the five-day field survey.

Lake Austin near Tom Miller Dam exhibited a rapid clearance of runoff-generated pollutant concentrations. Following the May 16 storm, high values for many water quality constituents began to drop off two days after the runoff event occurred. Throughout the survey period, higher BOD, COD, ammonia, ortho and total phosphorus, total dissolved solids, total suspended solids, and total nitrogen were detected in water samples from the downstream end of Lake Austin in comparison to samples taken in the lake upstream of Bull Creek. Other than raising the baseline water quality concentrations, however, the tributary runoff inputs did not appear to create conditions that were unfavorable for the resident biological community in the lake.

Storm Event Number 15 (5/24/81)

During the evening of May 24, 1981, a very intense thunderstorm system developed over Austin and proceeded to release large quantities of rainfall on the study area. Official rainfall at the Austin airport was 3.88 inches; however, the Bull Creek and Shoal Creek watersheds probably received considerably more than that amount. The intensity of the rainfall over a few hours duration resulted in massive flooding within both watersheds, causing loss of lives and property damage estimated in the millions. The floodwaters from this storm were sufficient to cause rises of several feet in both Lake Austin and Town Lake, and spillways on both reservoirs were opened to prevent flooding along these normally constant-level lakes. The floodwaters transported a tremendous amount of floating debris into the lakes from terrestrial sources, and also scoured the lake bottom in many areas freeing much rooted aquatic vegetation.

The actual water quality monitoring began on May 26, after water levels and flows had normalized. Large rafts of floating debris were present from the Loop 360 bridge to Tom Miller Dam. Since there were no significant releases from Lake Travis into Lake Austin during this period, the turbid floodwaters remained in place, rather than being displaced downstream out of the study area. A second survey was conducted on May 28 to assess the clearing rate for large-scale runoff events in the lake and its tributaries; however, a series of new thunderstorms with substantial rainfall caused heavy runoff due to saturated soil moisture conditions throughout area watersheds and the new inputs ended efforts to detect further water quality improvement following the Memorial Day floods.

Because of the massive runoff volume and its dilution effect, the magnitude of water quality modifications in Lake Austin were relatively small. Although ammonia, total phosphorus, and TSS concentrations increased to a certain extent, only 12.5 percent of the samples showed ammonia concentrations greater than 0.5 mg/l as is indicated by the data presented in Table 52. The waters in the lake due to this flood, however, were characterized by elevated numbers of fecal coliforms and high alkalinity (see Figures 44, 45).

Again, the upper arms of the Bull Creek and Dry Creek tributaries exhibited high levels of typical runoff-transported constituents. The turbid waters in upper Bull Creek improved in clarity as seepage waters displaced the original runoff waters into areas closer to the confluence with Lake Austin. Inflows into Dry Creek were not sufficient to move the runoff waters closer to the lake. Dissolved oxygen levels between five and six mg/l were noted in areas near tributary-lake confluences which have extensive rooted plant communities, perhaps indicative of the increased localized oxygen demand that results after several days of reduced light penetration caused by high turbidity.

Storm Events 23 (6/11/81) and 25 (7/5/81)

After receiving 3.98 and 2.14-inch storms on June 11, 1981 and July 5, 1981, water samples were taken from Lake Austin and Town Lake in order to

TABLE 52

WATER QUALITY CONDITIONS IN LAKE AUSTIN DURING THE STORM EVENT 15 (5/24/81)

Sampling Date	Parameter	Station							
		ES-0-0	ES-1-A	ES-1-B	ES-1-C	ES-2-A	ES-2-B	ES-2-C	ES-3
5-26-81	Alkalinity (mg/l)	130	234	220	160	220	196	138	126
	BOD$_5$ (mg/l)	2	1	1	1	4	6	2	2
	COD (mg/l)	4	4	4	4	11	57	8	4
	TOC (mg/l)	6.6	6.6	27.9	12.6	5.4	8.9	7.5	7.0
	Nitrogen, ammonia (mg/l)	0.44	0.48	0.68*	0.46	0.39	0.54*	0.44	0.09
	Nitrogen, nitrate (mg/l)	0.40	1.05	1.24	0.95	1.90	1.05	1.79	0.48
	Nitrogen, nitrite (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Nitrogen, total (mg/l)	0.72	0.66	0.81	1.18	1.39	1.21	1.03	0.94
	Ortho-phosphorus, total (mg/l)	<0.01	<0.01	0.01	0.01	<0.01	0.01	0.01	<0.01
	Phosphorus, Total (mg/l)	0.08	0.03	0.05	0.07	0.05	0.08	0.06	0.10
	Solids, Total Diss. (mg/l)	253	453	409	318	466	418	350	254
	Solids, Total Susp. (mg/l)	23	19	22	37	22	34	43	29
	Fecal Coliform (No./100 ml)	150	600	840	270	1,120	370	140	420
5-28-81	Alkalinity (mg/l)	144	314	240	198	222	192	144	154
	BOD$_5$ (mg/l)	2	1	2	2	2	3	3	1
	COD (mg/l)	38	46	30	38	38	38	42	46
	TOC (mg/l)	4.6	6.8	8.1	9.3	12.0	8.8	8.3	7.7
	Nitrogen, ammonia (mg/l)	0.27	0.24	0.26	0.38	0.14	0.15	0.36	0.28
	Nitrogen, nitrate (mg/l)	0.29	0.76	0.88	0.59	1.52	1.25	0.69	0.39
	Nitrogen, nitrite (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Nitrogen, total (mg/l)	0.84	0.92	0.91	0.81	0.95	1.03	1.21	0.89
	Ortho-phosphorus, total (mg/l)	0.01	0.02	<0.01	<0.01	<0.01	0.01	0.01	0.01
	Phosphorus, Total (mg/l)	0.05	0.03	0.03	0.06	0.05	0.06	0.08	0.06
	Solids, Total Diss. (mg/l)	306	374	410	383	403	381	294	272
	Solids, Total Susp. (mg/l)	7	5	22	17	18	15	14	13
	Fecal Coliform (No./100 ml)	70	70	100	200	110	210	190	140

*Value exceeded the allowable limitation.

FIGURE 44

FECAL COLIFORM CONCENTRATIONS IN LAKE AUSTIN AFTER STORM EVENT 15

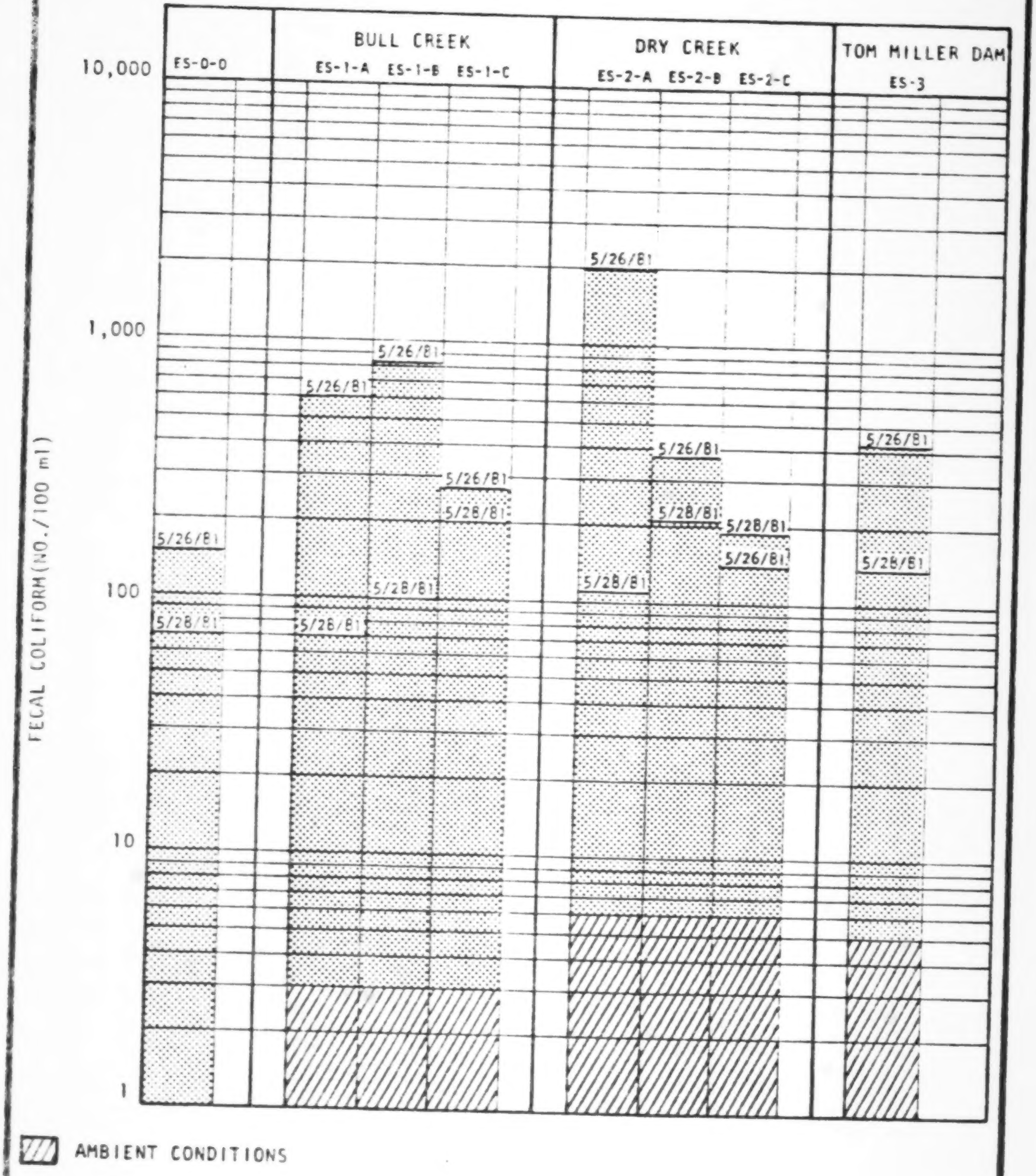
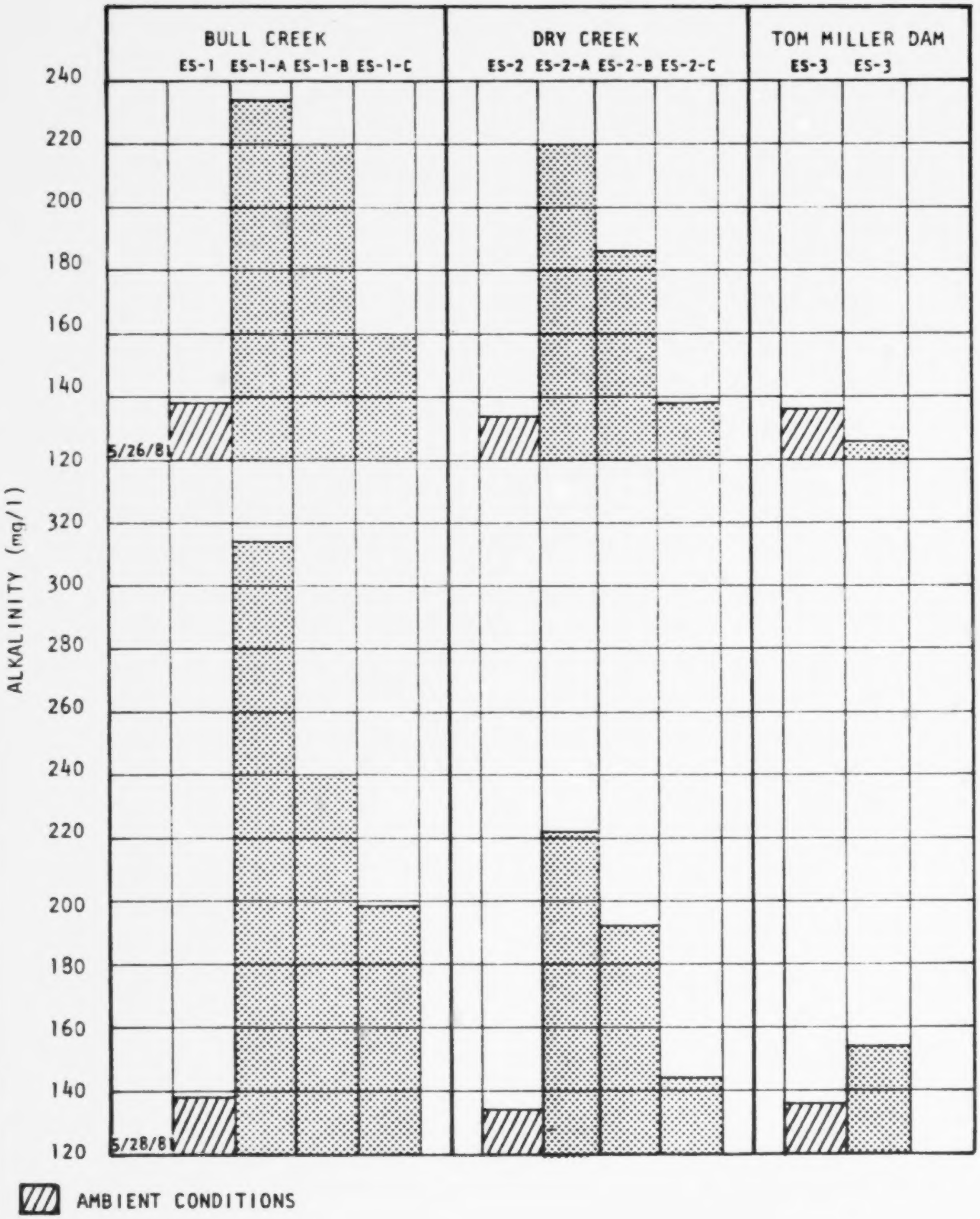


FIGURE 45

LAKE AUSTIN ALKALINITY DISTRIBUTION AFTER STORM EVENT 15



evaluate the impacts of the storm water runoff on water quality in these receiving bodies. Although both lakes showed similar results at elevated levels of certain water quality parameters, their magnitudes varied according to the characteristics of the lakes. These data are depicted in Tables 53, 54, 55, and 56. Alkalinity values were raised in both lakes, but to a lesser degree in Town Lake. Ammonia, nitrate, total phosphorus, TSS, and fecal coliform concentrations were increased in the same manner. Ammonia concentrations and fecal coliform levels were found to exceed the recommended limit on some occasions.

Summary

Water quality changes as measured in the tributaries to Town Lake and Lake Austin were documented by a series of storm event oriented water quality surveys. Data from these surveys indicated the following:

(1) Nonpoint source inputs into Town Lake and Lake Austin produced apparent water quality degradation in the tributaries. These impacts were short-lived, however, and the ambient water quality levels returned within three to five days of the runoff event.

(2) The apparent water quality impacts associated with nonpoint source inputs into the lakes proper were not as severe as that recorded in the tributaries. The waters in the main conservation pool near the dams of the two lakes exhibited a rapid clearance of runoff-generated pollutant concentrations after a given storm event.

(3) Generally, elevated levels of alkalinity, total organic carbon, BOD, COD, total nitrogen, ammonia, nitrate, orthophosphate, total phosphate, total suspended solids, and fecal coliforms were present in the lake waters during a nonpoint source event, however, a noticeable decline toward baseline levels was observed within three days of the storm event.

Quality Criteria Considerations

As water quality criteria specify concentrations of water constituents which are expected to result in an aquatic ecosystem suitable for the higher uses of water, these criteria levels are, therefore, intended to protect the

TABLE 53

WATER QUALITY CONDITIONS IN LAKE AUSTIN
AFTER STORM EVENT 23 (6/11/81)

Sampling Date	Parameter	Station									
		ES-0-A	ES-0-B	ES-0-0	ES-1-A	ES-1-B	ES-1-C	ES-2-A	ES-2-B	ES-2-C	ES-3
6-11-81	Alkalinity (mg/l)	232	138	136	238	228	222	246	224	164	148
	BOD_5 (mg/l)	1	1	3	1	1	2	2	1	2	1
	COD (mg/l)	8	4	4	4	19	15	23	11	34	15
	TOC (mg/l)	8.1	6.0	6.7	7.7	10.2	9.4	8.4	8.1	6.8	6.8
	Nitrogen, ammonia (mg/l)	0.77*	0.59*	0.67*	0.47	0.58*	0.70*	0.45	0.61*	0.82*	1.07*
	Nitrogen, nitrate (mg/l)	0.34	0.31	0.59	1.22	1.56	1.58	1.56	3.78	3.67	0.66
	Nitrogen, nitrite (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Nitrogen, Total (mg/l)	1.17	1.02	1.21	1.27	1.08	1.31	1.05	1.39	1.05	1.37
	Ortho-phosphorus, Diss. (mg/l)	<0.01	0.01	<0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01
	Phosphorus, Total (mg/l)	0.03	0.03	0.03	0.04	0.05	0.05	0.04	0.05	0.05	0.04
	Solids, Total Diss. (mg/l)	319	450	279	334	334	292	409	382	293	255
	Solids, Total Susp. (mg/l)	26	5	16	22	41	53	25	25	26	24
	Fecal Coliform (No./100 ml)	12	62	198	58	106	134	148	78	181	76

*Value exceeded the allowable limitation of 0.5 mg/l.

TABLE 54

WATER QUALITY CONDITIONS IN TOWN LAKE
AFTER STORM EVENT 23

Sampling Date	Parameter	Station				
		ES-4	ES-5	ES-6	ES-7	ES-8
6-11-81	Alkalinity (mg/l)	140	142	158	158	142
	BOD_5 (mg/l)	1	1	1	1	1
	COD (mg/l)	61	65	38	95	76
	TOC (mg/l)	6.6	6.3	8.4	14.2	6.4
	Nitrogen, ammonia (mg/l)	0.95*	1.07*	1.33*	1.70*	0.89*
	Nitrogen, nitrate (mg/l)	0.61	0.83	0.81	0.61	1.39
	Nitrogen, nitrite (mg/l)	<0.01	0.01	<0.01	<0.01	0.02
	Nitrogen, total (mg/l)	1.08	1.39	2.06	3.22	1.29
	Ortho-phosphorus, Diss. (mg/l)	0.03	0.02	0.01	0.01	0.05
	Phosphorus, Total (mg/l)	0.04	0.05	0.10	0.13	0.08
	Solids, Total Diss. (mg/l)	328	289	307	235	320
	Solids, Total Susp. (mg/l)	11	74	209	300	45
	Fecal Coliform (No./100 ml)	76	88	94	TNTC**	106

*Value exceeded the allowable limitation of 0.5 mg/l.

**Too numerous to count.

TABLE 55

WATER QUALITY CONDITIONS IN LAKE AUSTIN AFTER STORM EVENT 25 (7/05/81)

Sampling Date	Parameter	Station									
		ES-0-A	ES-0-B	ES-0-D	ES-1-A	ES-1-B	ES-1-C	ES-2-A	ES-2-B	ES-2-C	ES-3
7-6-81	Alkalinity (mg/l)	144	164	140	218	226	156	154	154	146	154
	BOD$_5$ (mg/l)	1	1	1	1	1	1	1	1	1	1
	COD (mg/l)	11	4	7	4	4	18	11	11	4	4
	TOC (mg/l)	15.3	6.4	6.5	8.4	7.6	5.4	4.9	5.3	4.4	4.5
	Nitrogen, ammonia (mg/l)	0.47	0.67*	0.52*	0.49	0.75*	0.73*	0.57*	0.57*	0.39	0.50
	Nitrogen, nitrate (mg/l)	0.13	0.11	0.14	0.54	0.59	0.28	0.49	0.34	0.21	0.11
	Nitrogen, nitrite (mg/l)	<0.01	0.01	<0.01	0.01	0.01	0.01	0.02	0.01	<0.01	<0.01
	Nitrogen, total (mg/l)	0.99	0.94	1.09	0.93	0.89	1.00	1.03	1.03	0.84	1.01
	Ortho-phosphorus, Diss. (mg/l)	<0.01	<0.01	<0.01	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Phosphorus, total (mg/l)	0.03	0.03	0.03	0.03	0.05	0.03	0.06	0.06	0.01	<0.01
	Solids, Total Diss. (mg/l)	261	283	278	262	244	260	248	243	271	234
	Solids, Total Susp. (mg/l)	8	8	9	33	67	23	41	37	6	9
	Fecal Coliform (No./100 ml)	142	186	168	TNTC**	TNTC**	TNTC**	TNTC**	TNTC**	86	78
7-9-81	Alkalinity (mg/l)	140	168	136	212	214	174	176	184	156	142
	BOD$_5$ (mg/l)	2	1	1	1	1	1	1	1	1	1
	COD (mg/l)	4	4	4	4	29	11	4	11	7	7
	TOC (mg/l)	8.9	4.4	5.4	4.6	4.1	4.7	6.3	4.5	6.6	4.0
	Nitrogen, ammonia (mg/l)	0.43	0.45	0.11	0.31	0.09	0.14	0.20	0.10	0.02	0.10
	Nitrogen, nitrate (mg/l)	0.19	0.22	0.11	0.32	0.41	0.27	0.32	0.21	0.22	0.11
	Nitrogen, nitrite (mg/l)	<0.01	<0.01	<0.01	0.01	0.01	0.01	<0.01	0.01	0.01	<0.01
	Nitrogen, total (mg/l)	1.25	1.37	1.42	1.26	1.33	1.24	1.53	1.42	1.60	1.35
	Ortho-phosphorus, Diss. (mg/l)	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Phosphorus, Total (mg/l)	<0.01	0.02	<0.01	0.03	0.03	0.02	0.05	0.03	0.03	<0.01
	Solids, Total Diss. (mg/l)	393	425	346	369	380	361	357	360	338	358
	Solids, Total Susp. (mg/l)	7	14	9	72	48	19	30	27	23	9
	Fecal Coliform (No./100 ml)	270	500	30	130	2,030	180	1,070	220	60	110

*Value exceeded the limitation of 0.5 mg/l.

**Too numerous to count.

TABLE 56

WATER QUALITY CONDITIONS IN TOWN LAKE AFTER STORM EVENT 25 (7/05/81)

Sampling Date	Parameter	Station				
		ES-4	ES-5	ES-6	ES-7	ES-8
7-6-81	Alkalinity (mg/l)	144	146	150	210	120
	BOD_5 (mg/l)	1	2	2	1	1
	COD (mg/l)	4	4	4	4	4
	TOC (mg/l)	2.4	4.4	4.5	3.0	7.0
	Nitrogen, ammonia (mg/l)	0.45	0.36	0.43	0.35	0.29
	Nitrogen, nitrate (mg/l)	0.22	0.16	0.22	0.88	0.81
	Nitrogen, nitrite (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01
	Nitrogen, total (mg/l)	0.99	1.10	1.17	0.78	1.08
	Ortho-phosphorus, Diss. (mg/l)	<0.01	<0.01	<0.01	<0.01	0.05
	Phosphorus, Total (mg/l)	<0.01	<0.01	0.03	0.03	0.08
	Solids, Total Diss. (mg/l)	446	413	374	362	418
	Solids, Total Susp. (mg/l)	6	11	17	25	6
	Fecal Coliform (No./100 ml)	*	221	TNTC**	TNTC**	TNTC**
7-9-81	Alkalinity (mg/l)	146	146	152	220	142
	BOD_5 (mg/l)	1	1	1	1	1
	COD (mg/l)	7	4	4	4	14
	TOC (mg/l)	5.2	4.4	3.7	1.7	3.6
	Nitrogen, ammonia (mg/l)	0.23	0.30	0.30	0.18	0.23
	Nitrogen, nitrate (mg/l)	0.27	0.25	0.23	0.84	0.29
	Nitrogen, nitrite (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01
	Nitrogen, total (mg/l)	1.44	1.44	1.36	1.20	1.33
	Ortho-phosphorus, Diss. (mg/l)	<0.01	<0.01	<0.01	<0.01	0.01
	Phosphorus, Total (mg/l)	0.03	0.03	0.02	0.01	0.03
	Solids, Total Diss. (mg/l)	345	337	333	251	301
	Solids, Total Susp. (mg/l)	12	6	3	26	11
	Fecal Coliform (No./100 ml)	2,160	150	460	910	870

*Atypical growth.

**TNTC = too numerous to count.

essential and significant life in water as well as the direct uses of water. Since the Austin NURP study was concerned with the impacts of storm runoff on lake receiving water and aquatic life, the quality levels considered in the evaluation are based on the protection of water supply, recreation resources, and any aquatic life that may be consumed as part of our diet. These quality criteria, however, vary according to the degree of hazard associated with the principal concerns as shown in Table 57.

It is clear that the criteria for water supply quality attempt to achieve a degree of safety that will protect against any acute or chronic effects that may occur from public drinking water. These criteria are based on the assumption that an average person will consume about two liters of water daily. The water quality criteria for recreation and aesthetics, on the other hand, are intended to enhance and preserve the recreational and aesthetic values of water resources. The aquatic life criteria levels also differ from the criteria presented for water supply and recreation in that they are based on certain hazardous effects caused by a given amount of intake of a particular contaminated organism per unit of time. Owing to sparse existing data obtained from previous studies, and the variety of organisms that may be present in a contaminated ecosystem (which greatly increases the complexity of the problem), the quality criteria for aquatic life are not standardized in the same manner as the criteria established for water supply and recreation. At present, the aquatic life criteria are based on the amount of daily consumption of each constituent that may cause a given hazardous effect.

During the survey period ammonia, nitrate, phosphorus, fecal coliform, and total suspended solids seemed to be the major pollutant parameters that were significantly affected by storm runoff. Their concentrations in the receiving water after a given storm event can be compared to pertinent water supply standards for public safety. These data show that ammonia concentrations present in the waters from certain receiving water stations exceeded the standard after a rain. Although ammonia nitrogen is considered toxic to aquatic organisms, the higher concentrations that resulted from storm runoff are not likely to have any effect on the aquatic life because they are localized and have a rather rapid translocation rate due to high stream flow. Therefore, the concentrations of ammonia in the water column after storm runoff do not reveal the real condition of the water body and the exceedances

TABLE 57

QUALITY CRITERIA FOR WATER AND ITS RELATED IMPACTS

Parameter	Drinking Water Standard (mg/l)	Freshwater Aquatic Life Standard (mg/kg tissue)	Allowable Average Daily Intake[a] (mg/day)	Protection of Aquatic Life Standard (µg/l)
pH[b]	5.0-9.0[c]	-	-	6.5-9.0[c]
Fecal Coliforms[d]	200.0[c,i]	-	-	14[c,j]
Ammonia-nitrogen	0.5[e]	-	-	20[c,k]
Nitrate-nitrogen	10.0[c]	-	-	-
Total Suspended Solids	-	-	-	-[c,l]
Metals:				
Arsenic	0.05[c]	-	0.70[f]	-
Cadmium	0.01[c]	-	0.018[f]	12[m,c]
Copper	1.00[c]	-	3.20[f]	-
Mercury	0.002[c]	1.00[g]	0.03[f]	0.05[c]
Lead	0.05[c]	-	0.30[f]	30[e]
Zinc	5.00[c]	-	12.00[f]	-
Pesticides:				
DDD	-	5.00[h]	-	-
DDE	-	5.00[h]	-	-
DDT	-	5.00[h]	-	0.001[c]
PCBs	-	5.00[h]	-	0.001[c]

[a] Average daily intake that will not be harmful to a normal person.

[b] pH unit.

[c] Quality Criteria for Water (U.S. EPA, 1976).

[d] No./100 ml.

[e] Water Quality Criteria, 1972, National Academy of Sciences.

[f] Personal communication with Texas State Health Department (1982).

[g] Most recent U.S. FDA guideline for mercury in edible fish.

[h] Texas Department of Water Resources (Report 264, 1982).

[i] For bathing waters.

[j] For shellfish harvesting waters.

[k] As unionized ammonia.

[l] Settleable and suspended solids should not reduce the depth of the compensation point for photosynthetic activity by more than 10 percent from the seasonally established norm for aquatic life.

[m] For aquatic life exclusive of cladocerans and salmonid which are more sensitive.

of the ammonia criterion in this situation may not present a public health risk.

The pH standard range is set between 6.5-9.0 within the range of most natural waters. Studies show that pH values below the lower limit of the standard range tend to increase the corrosive effect of heavy metals. The Austin NURP data relative to storm water runoff indicated that no violations of this standard would occur at any time.

As the number of fecal coliforms present in the water body and the level of turbidity are the common factors used to determine the suitability of water resources for recreation, their fluctuation during storm runoff events are a major concern when assessing the impact associated with recreational activities. Since turbidity alone is not considered a suitable measure of water quality, the number of fecal coliforms present in the receiving water can be used to determine the degree of safety associated with recreational uses. These data show that the numbers of fecal coliforms present in the waters from both lakes exceeded the standard after a given rain storm. Since a high fecal coliform number in the waters of Lake Austin is usually accompanied by a high stream flow associated with the input of large volumes of runoff, recreational activities after a rain are in all probability kept to a minimum and these periodic violations in water quality do not appear to have a hazardous effect on public health. Although, Town Lake shares the condition with Lake Austin of a high fecal coliform number after a given rainfall event, the numbers of fecal coliforms during the normal dry periods present in Town Lake water still exceeded the standard level of 200 per 100 milliliters of water from time to time. Since this condition appears to be the normal water quality in Town Lake, contact recreation is, therefore, not recommended until the water quality can be improved.

Phosphorus and total suspended solids concentrations also increased during a given storm event, however, quality standards regarding phosphorus and suspended solids in the freshwater environment are not available at present. It is known that phosphorus in the elemental form is particularly toxic and can be accumulated in much the same way as mercury. Phosphorus as phosphate, however, is one of the major nutrients required for plant nutrition and, therefore, no national criterion is presently proposed for phosphate phosphorus. Total suspended solids, have no apparent effect on aquatic life when a high concentration only occurs for a short period of time. Suspended solids can also be easily removed from the water supply by sedimentation and filtration, therefore, there is no criterion set for total suspended solids in the receiving water.

Among the constituents present in storm runoff, metals and chlorinated hydrocarbons may be considered the most important parameters from a public health standpoint. The hazardous effects of metals on aquatic life are well recognized and standards are set according to their toxic effects. None of the Austin NURP data show that the presence of metals in the receiving water or the fish tissue samples collected during the study can cause a hazard to public health. The criteria for fish tissue are much higher than those for the water supply because an average person is assumed to consume not more than two pounds of fish per week as compared to a volume of two liters of water per day.

Similar to the metal criteria, the chlorinated hydrocarbon standard levels are based on their toxic effects. Since the chlorinated hydrocarbons which the study emphasized were insoluble in water, their standard levels are available only in the tissue where they can be accumulated in the lipid medium of the adipose tissue. There is one criterion set for a combination of DDT, DDE, and DDD because DDE and DDD are the breakdown products of DDT, and these three compounds show similar effects on aquatic life and man. None of the Austin NURP fish samples violated the PCB standard of 5,000 micrograms/kg and only one sample violated the DDT complex standard of 5,000 micrograms/kg. Since the DDT complex is carcinogenic, this substance in the two lakes requires more attention and further research in this area is recommended so that the public health can be protected.

The Effects of Runoff Loadings on the Cost of Chemical Treatment of Drinking Water

Although the primary impacts of urban runoff loadings on lake water quality are associated with an increase in ammonia-nitrogen, suspended solids, fecal coliforms, and oil and grease, storm water runoff also modifies some of the chemical properties of the receiving water such as alkalinity and hardness. These impacts on water quality in turn lead to a secondary impact in terms of an increase in the treatment cost of drinking water. Since the overall cost for treating raw water is directly proportional to the cost of the chemical requirement, it is therefore possible to predict the change in treatment cost associated with a given modification in the water quality of the receiving water after the rainfall. However, the cost data presented herein do not represent the true costs of raw water treatment because of the lack of documentation relative to operating cost information during the treatment process.

In order to determine the water treatment cost associated with the input of storm water runoff to a receiving water body, the chemical costs for treating water alkalinity and hardness are considered the baseline chemical costs due to their relatively small fluctuations. On the other hand, the chemical cost associated with treating raw water for the removal of coliforms, oil and grease, and taste and odor is taken as the cost most readily affected by storm water runoff inputs. Since the water quality sampling stations were located in both Town Lake and Lake Austin, cost data from the Davis Water Treatment Plant were used to determine the chemical cost for treatment of drinking water for the following reasons:

(1) Although Town Lake appears to be more affected by the storm water runoff loadings than does Lake Austin, the Green Water Treatment Plant usually shuts down during storm periods, and thus does not provide sufficient data with which to conduct a meaningful evaluation.

(2) The location of the Davis Water Treatment Plant raw water intake is in the main pool of Lake Austin, and this provides fairly accurate information relative to the lake water quality.

The evaluation of available water treatment plant operational data indicated that an increase in the chemical treatment cost of drinking water was not obvious with cumulative rainfall volumes less than one inch. Since the total treatment cost also is associated with the amount of water to be treated as well as the water quality, a daily data record which incorporates a period of at least five consecutive days was used to emphasize this relationship. By considering water quality and water treatment cost data taken during the dry period as the baseline information, a comparison of the incremental increase in chemical treatment cost was made for different cumulative rainfall volumes such as volumes of greater than one, two, and three inches.

Treatment Cost Associated with Alkalinity and Hardness

Figure 46 presents cost data that show that the costs of treatment relative to the level of alkalinity and hardness of the lake water were not only related to the runoff, but also to the time of the year. In general, water alkalinity and hardness levels were elevated after the storm periods because of the presence of limestone in the surrounding terrain as shown by the Austin NURP data collected during May, 1981 (see Table 58). These higher levels of alkalinity and hardness, in turn, created a higher chemical demand for the treatment of raw lake water, thus raising the treatment cost. However, the early spring rain (see Figure 46) seemed to deviate from this condition because of lower ambient alkalinity and hardness levels, thus lowering the treatment cost.

Treatment Cost Associated with the Storm Water Runoff Generated Pollutants

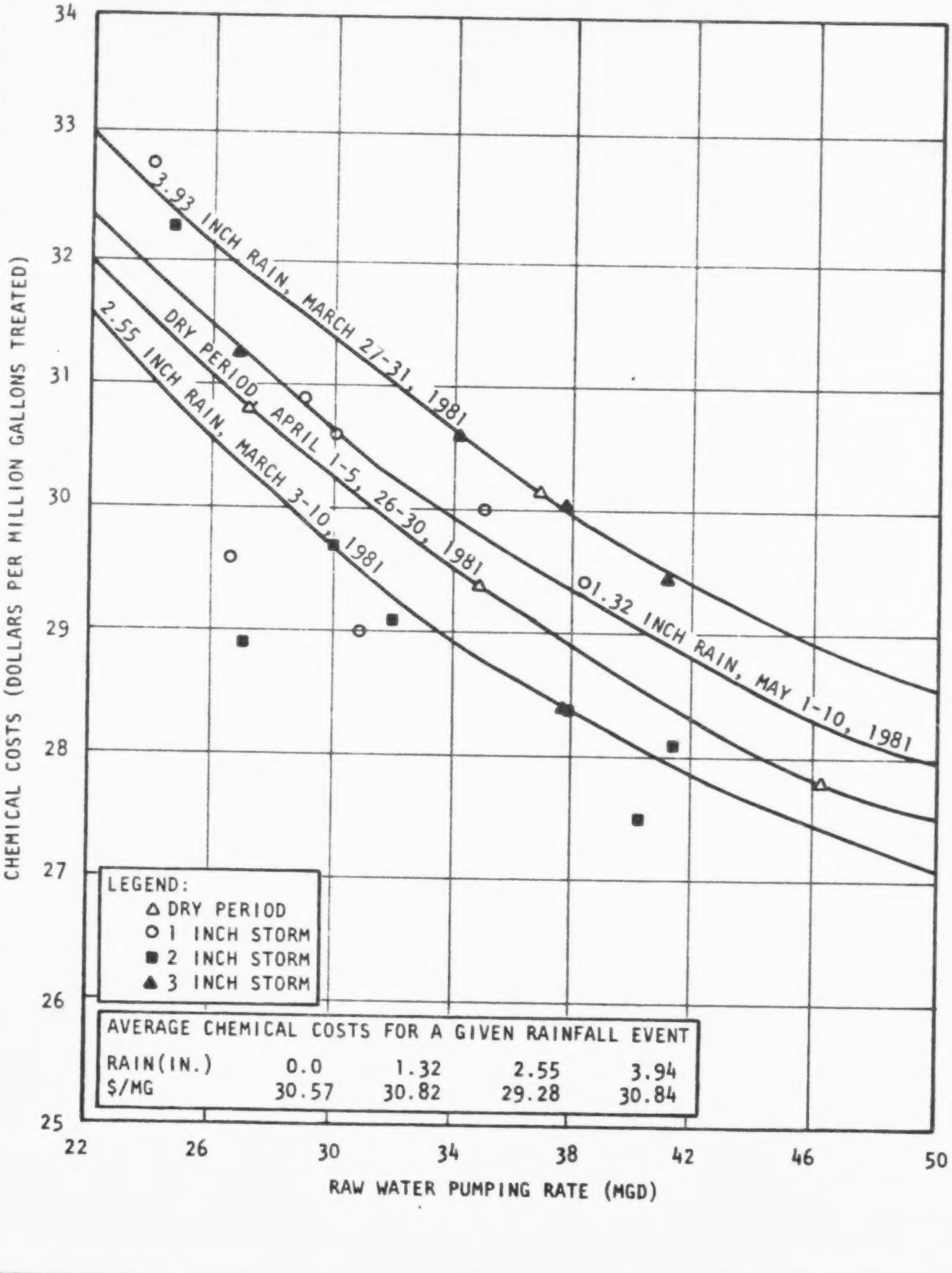
Data collected during the period of 1980 through 1981 clearly indicated an increase in chemical demand and, therefore, chemical cost for treating fecal coliforms, oil and grease, and taste and odor in raw water after a given storm period (see Figue 47). However, the cost associated with the runoff appeared to be related to such temporal factors as time of the year, the duration of the storm, and the length of the dry period (antecedent conditions). The first storm of the year, as indicated by the 2.55-inch rain in Figure 47, showed a significantly higher treatment cost as compared to those obtained during the dry period and the later storms.

Total Chemical Cost Associated with the Treatment of Lake Waters

It is clear that the total chemical cost associated with the treatment of drinking water was affected by storm water runoff quality as shown in Figure 48. These data suggest that the incremental increase in total treatment cost was strongly related to the cost associated with treating coliforms, oil and grease, and taste and odor which are generated from the storm water runoff. For instance, the 2.55-inch storm event data showed a lower cost associated with the treatment for alkalinity and hardness reduction than the baseline value obtained during the dry period (see Figure 46), but a markedly higher cost associated with the treatment of storm water runoff-related pollution (see Figure 47), thus resulting in a significant increase in the total

FIGURE 46

COSTS ASSOCIATED WITH ALKALINITY AND HARDNESS IN THE TREATMENT OF LAKE WATER



AVERAGE CHEMICAL COSTS FOR A GIVEN RAINFALL EVENT

RAIN(IN.)	0.0	1.32	2.55	3.94
$/MG	30.57	30.82	29.28	30.84

TABLE 58

EFFECTS OF THE RUNOFF ON ALKALINITY OF LAKE AUSTIN RECEIVING WATER

Storm Event No.* (Rain in Inches)	Date	Station							
		ES-0-0	ES-1-A	ES-1-B	ES-1-C	ES-2-A	ES-2-B	ES-2-C	ES-3
13 (1.32)	5-1-81**	134	148	134	134	126	136	140	138
	5-3-81	140	188	146	144	144	144	140	138
	5-4-81	140	178	150	142	158	140	142	144
	5-5-81	138	172	150	144	148	142	138	148
14 (1.24)	5-16-81	144	144	148	148	146	138	132	144
	5-17-81	144	186	152	148	148	138	140	140
	5-18-81	146	186	150	152	142	146	136	144
	5-20-81	134	152	148	148	156	142	138	126
15 (6.24)	5-26-81	130	314***	220	160	220	186	138	126
	5-28-81	144	234	240	198	222	192	144	154

NOTES: ES-0-0 is upstream of Bull Creek station.
ES-1-A, ES-1-B and ES-1-C are Bull Creek stations.
ES-2-A, ES-2-B and ES-2-C are Dry Creek stations.
ES-3 is the Tom Miller Dam station.

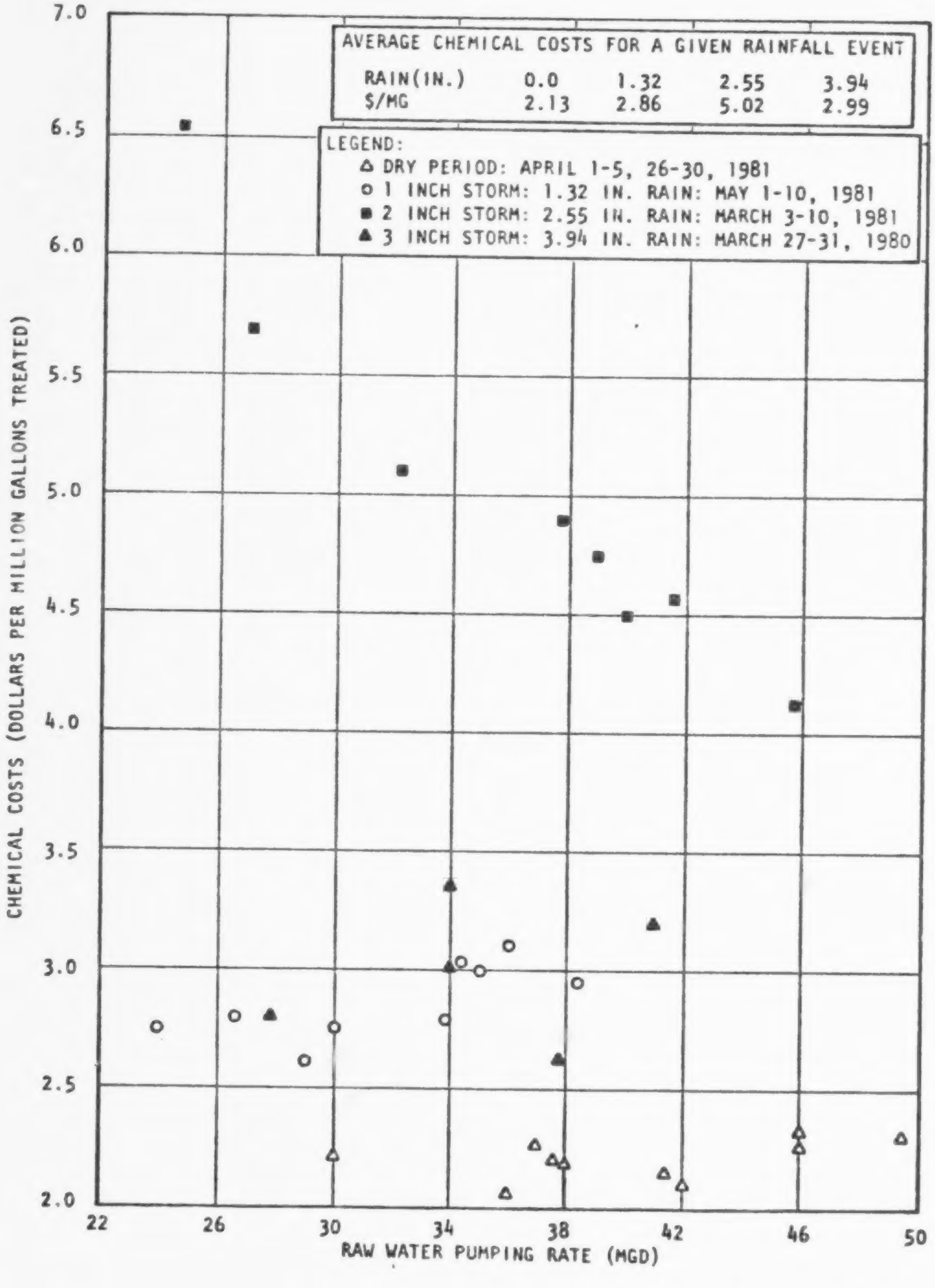
*As mentioned in the previous sections.

**Baseline level.

***High local spring flow effect.

FIGURE 47

COSTS ASSOCIATED WITH CHLORINE, AMMONIA, AND ACTIVATED CARBON IN THE TREATMENT OF LAKE WATER

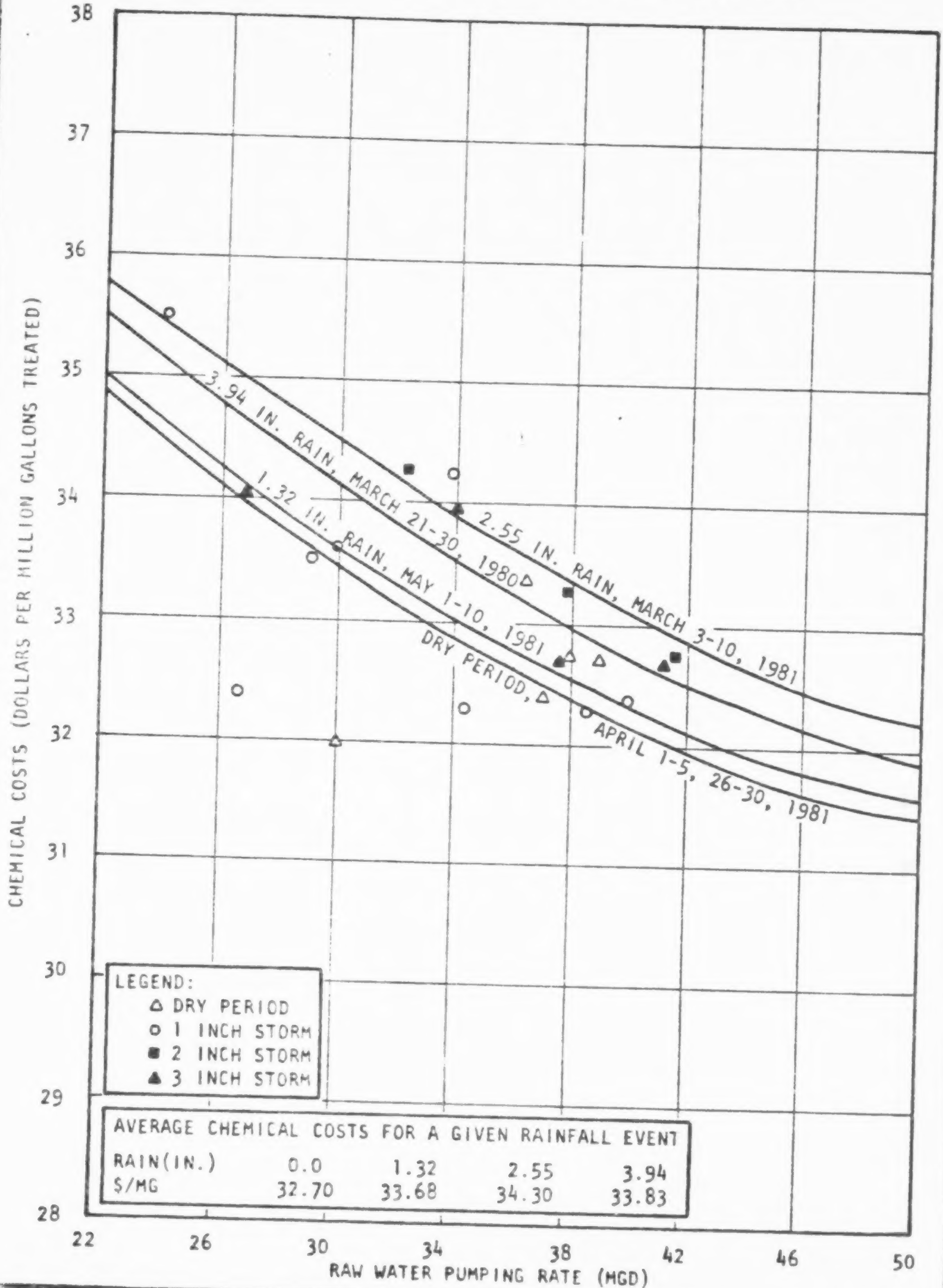


AVERAGE CHEMICAL COSTS FOR A GIVEN RAINFALL EVENT

RAIN(IN.)	0.0	1.32	2.55	3.94
$/MG	2.13	2.86	5.02	2.99

FIGURE 48

TOTAL CHEMICAL COSTS FOR TREATMENT OF LAKE WATERS



AVERAGE CHEMICAL COSTS FOR A GIVEN RAINFALL EVENT

RAIN(IN.)	0.0	1.32	2.55	3.94
$/MG	32.70	33.68	34.30	33.83

treatment cost as depicted in Figure 48. Therefore, it is noted that the pollutional impact of the storm water runoff on water treatment costs is apparent, and the magnitude of the impact depends on the following factors:

(1) time of the year;
(2) the length of the dry period prior to a storm event;
(3) the storm duration; and
(4) the storm intensity.

A summary of the chemical costs for treatment of Austin drinking water is shown in Table 59.

Considerations Regarding a Special Case

The Memorial Day flood was taken as a special case relative to the impact of storm water runoff on the cost of treatment of Austin drinking water. The high cumulative rainfall volume of 6.24 inches during May 24, 1981 (as measured at the Davis Water Treatment Plant) resulted in massive flooding in both the Lake Austin and Town Lake watersheds and transported a tremendous amount of debris into the lakes. The heavy runoff also produced an excessive amount of oil and grease in the waters of the lakes, especially Town Lake. Again, the data evaluated in this section were obtained from Davis Water Treatment Plant records, since the Green Water Treatment Plant was shut down because of the excessive oil and grease levels in the intake water.

In this case, the runoff quality impact on the treatment cost are shown to be a function of time, and not of volume of rainfall. This was because the Memorial Day 6.24-inch rainfall was followed by a series of smaller storms ranging from 0.16 to 3.98 inches during a period of three weeks. This multiple storm series and the associated flood control measures in the lakes caused such runoff constituents as terrestrial debris, organic matter, oil and grease, taste and odor, coliform bacteria, and possibly toxic materials to remain in the lake waters much longer than the normal lag period of five days after each storm.

The data in Figure 49 indicate that the cost of treatment for alkalinity and hardness reduction was incrementally higher throughout the affected period. However, the cost fluctuated with the cumulative rainfall volume. These data indicate a maximum cost of $38.57 per million gallons treated, or

TABLE 59

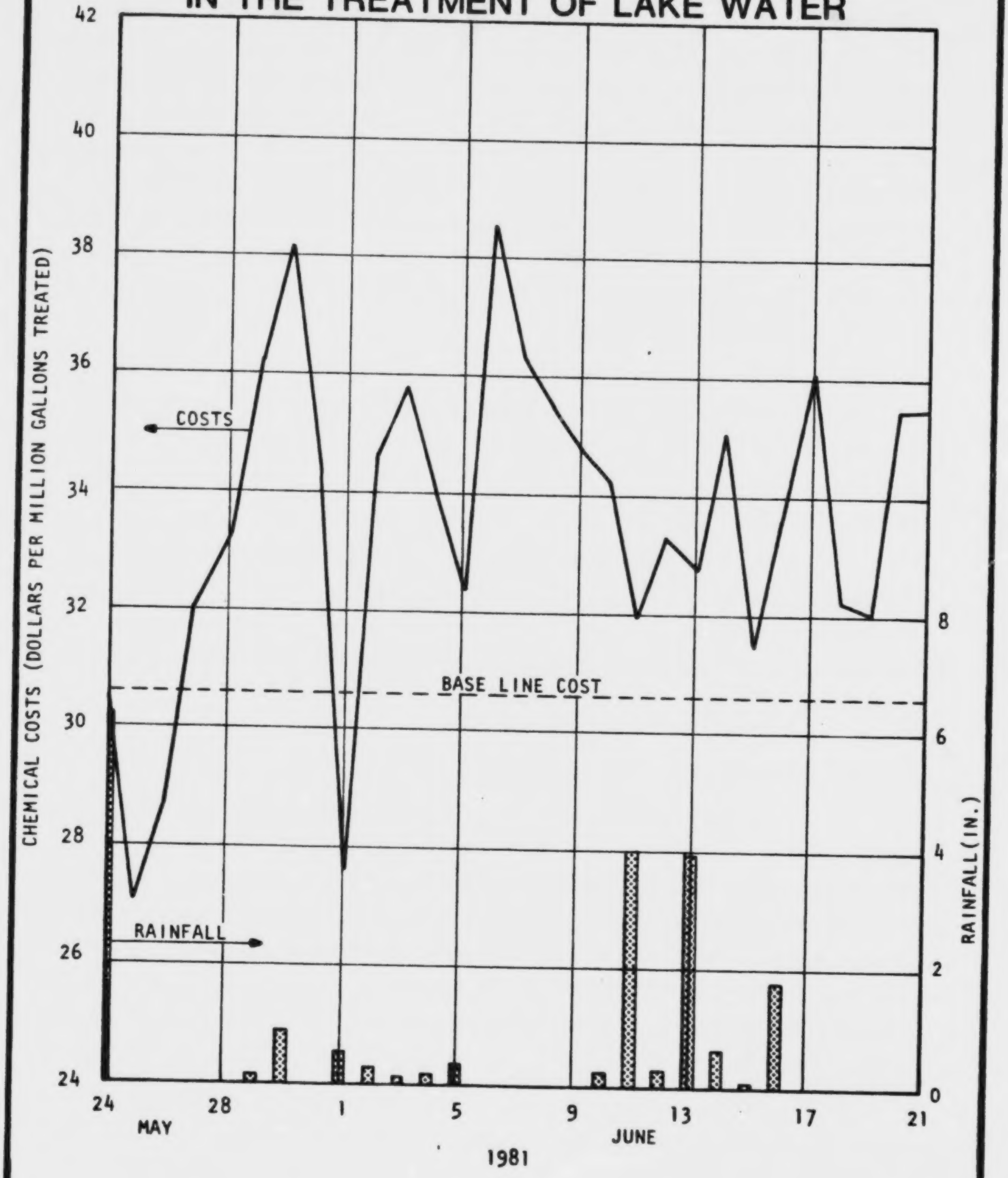
TOTAL CHEMICAL TREATMENT COST

Rainfall Event (inches)	Cost Increment Associated With Alkalinity-Hardness Reduction ($/MG)	Cost Increment Associated With the Runoff Pollutants ($/MG)	Total Chemical Cost ($/MG)
0.0	30.57	2.13**	32.70
1.32	30.82	2.86	33.68
2.55*	29.28	5.02	34.30
3.94	30.84	2.99	33.83

*Multiple storm in early spring.

**Base chemical usage.

COSTS ASSOCIATED WITH ALKALINITY, HARDNESS, AND TOTAL SUSPENDED SOLIDS IN THE TREATMENT OF LAKE WATER



a maximum incremental increase of $8.00 per million gallons treated, which results in a 26 percent increase from the baseline of $30.57 per million gallons obtained during the dry period in April, 1981.

The treatment cost associated with the characteristic urban runoff pollutants increased significantly as a result of the Memorial Day flood. Although the increase in chemical cost fluctuated in the same manner as the cost associated with raw water treatment for removal of alkalinity and hardness, a marked increase lasted for a period of one week after the first storm event (see Figure 50). The maximum chemical cost associated with the runoff was found to be $19.71 per million gallons treated, and this resulted in an increase of $17.58 per million gallons from the baseline cost of $2.13 per million gallons, or 825 percent.

When the costs associated with the changes in water quality were combined to give the total cost as shown in Figure 51, the maximum cost was found to be $57.86 per million gallons treated as compared to $32.70 per million gallons obtained during the dry period. This gave a total chemical cost rise of 77 percent, or $25.16 per million gallons.

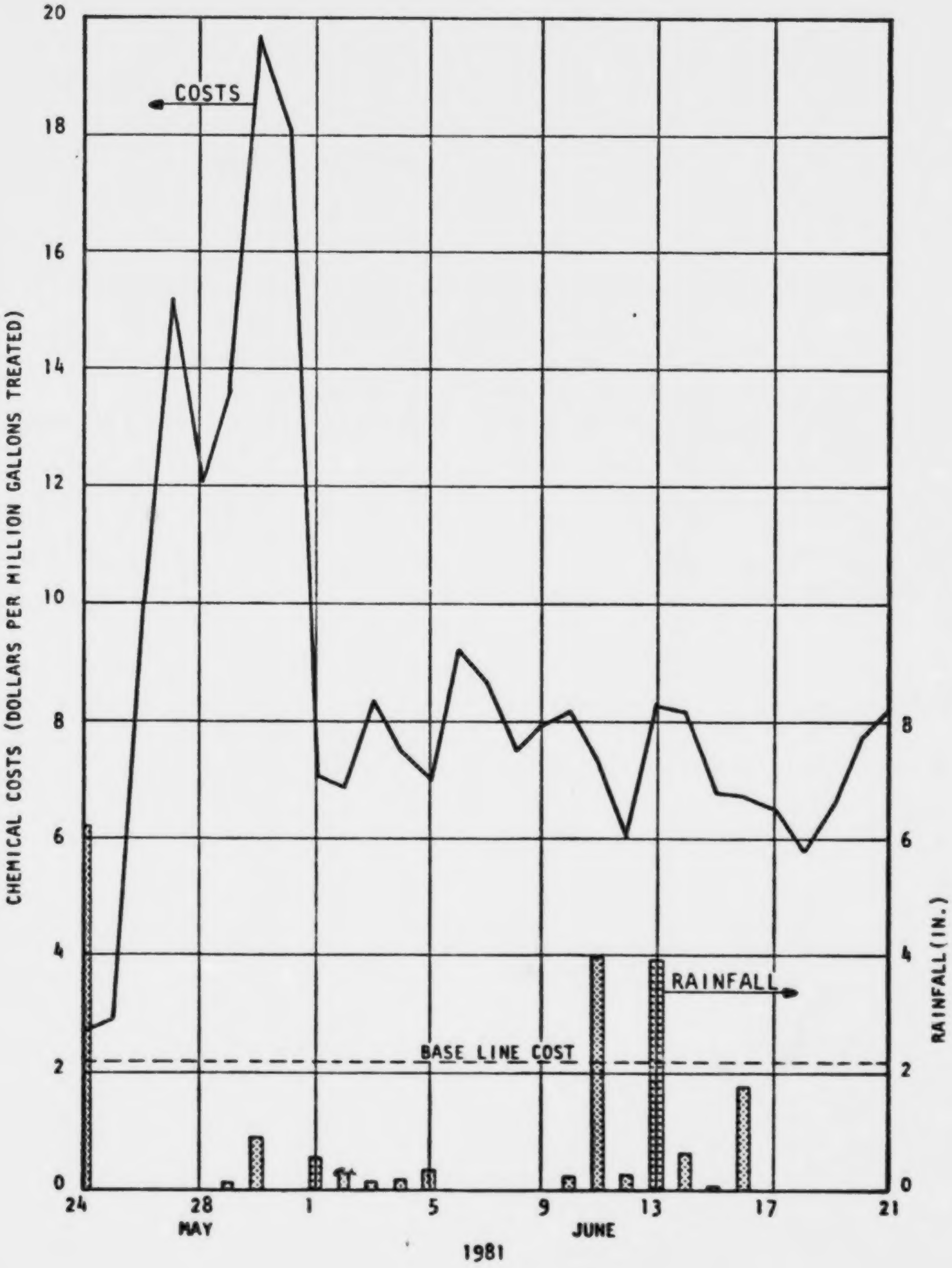
Therefore, this special case showed that the total treatment cost was sensitive to the cost associated with the treatment of constituents present in polluted runoff as well as the cumulative storm water volume. The lag period for a given impact was shown to be a function of the number of storms in a given time period and their relative cumulative rainfall volume.

COST/BENEFIT ANALYSIS

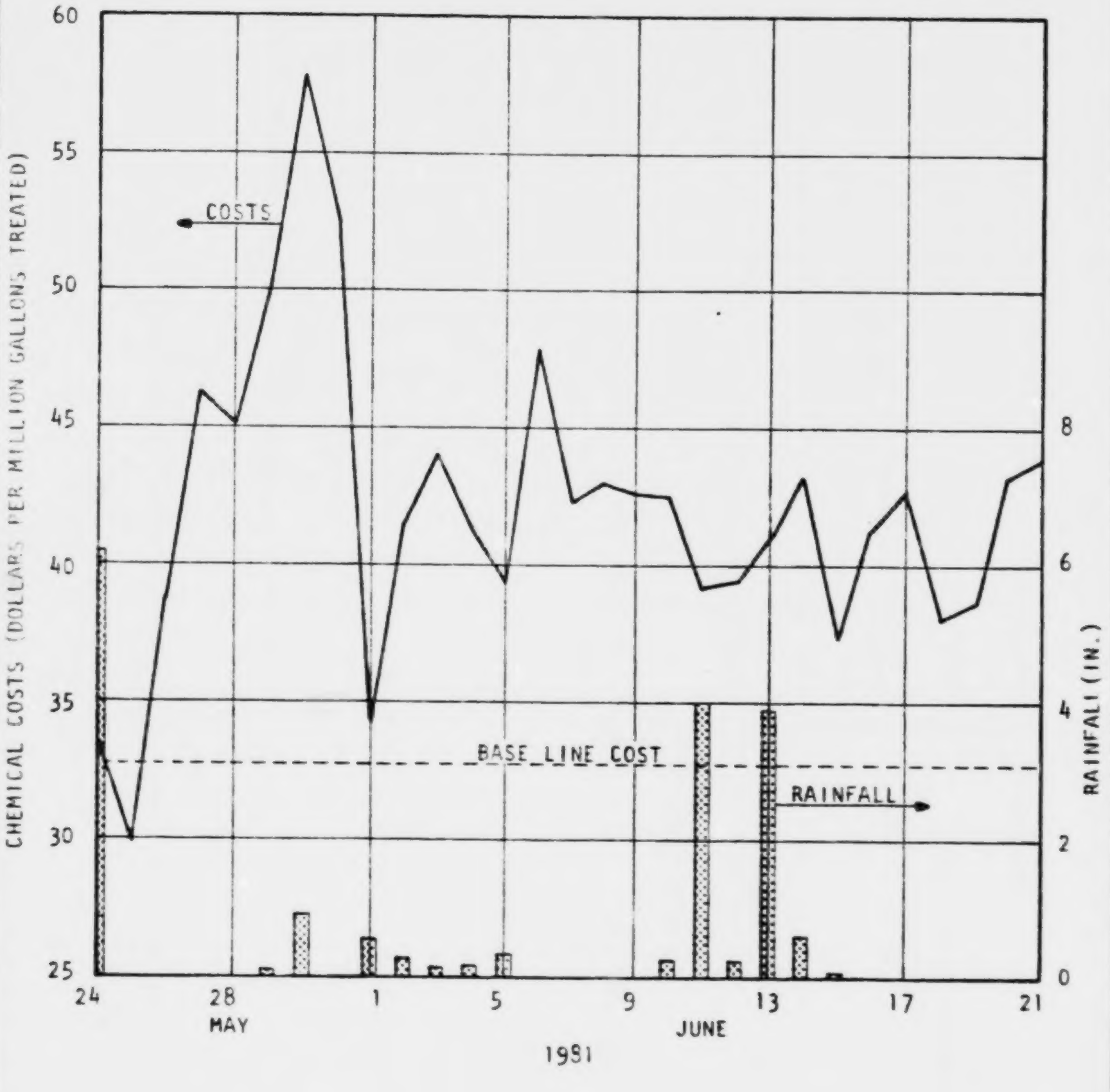
An initial objective of this study was to establish the merit of a given urban-related storm water quality control measure according to the incremental cost principle such that the most cost-effective method of control can be determined. According to this principle, the change in benefits and the change in costs resulting from a given urban runoff control measure determine the merit of the implementation of that measure. This type of analysis, if feasible, is desirable to allow selection of the most cost-effective runoff control measure.

Unfortunately, only one structural control measure, the Woodhollow storm water detention basin at the Northwest Austin site, was available for

COSTS ASSOCIATED WITH THE RUNOFF POLLUTANTS IN THE TREATMENT OF LAKE WATER



TOTAL CHEMICAL COSTS IN THE TREATMENT OF LAKE WATER



evaluation during this study. As discussed earlier in this report, the Woodhollow storm water detention basin is designed for flood control rather than control of the pollutants in urban runoff and thus its design basis is not necessarily the most cost-effective for removing pollutants from urban runoff. In addition, only three storms provided sufficient data for an evaluation of the performance of this structure for removing pollutants, and one of these events caused such a short hydraulic detention time in the basin that its capability for removing suspended solids was exceeded. Thus, no reliable estimate of the cost/benefit of structural controls, as represented by a storm water retention basin, is possible from the data base compiled during this study. The data which have been collected for the operation of this structure and which are presented in this report, however, can be utilized to determine, in a qualitative sense, the cost/benefit of this structure in the context of its efficiency for removal of suspended solids during the two events in which it was functioning correctly.

As shown in Table 34 of this report, the March 7 and September 14 events provided sufficient information to allow an estimate of the percent removal of total suspended solids by the Woodhollow storm water detention basin. An average of 75 percent removal of total suspended solids was observed for these two events. If the estimated annual loading for the Northwest Hills site, as presented in Table 31, is used with the size of the Northwest Austin drainage basin, it is estimated that 27,769 pounds of total suspended solids per year are discharged in the urban runoff influent to the Woodhollow detention basin. If it is assumed that the average removal of total suspended solids by the basin is 75 percent, then 20,827 pounds of total suspended solids per year would be removed by the detention basin, on the average. Based on City of Austin records, the approximate capital cost of the Woodhollow storm water detention basin is $500,000. Based on an interest rate of 10 percent and an effective life of the detention basin of 20 years, the cost per pound of total suspended solids removed on an average annual basis is $2.80, neglecting operational costs.

To perform a true cost/benefit analysis of this structural control, an estimate would be needed of the market and nonmarket costs and benefits associated with urban runoff in the Austin area. As an example, it is indicated in Table 59 that the incremental cost of water treatment plant chemicals associated with the treatment of urban runoff-related pollutants ranges between $2.13 and $5.02 per million gallons of water treated. This is a direct market cost of urban runoff. In addition, certain nonmarket costs of urban runoff such as decreased recreational usage of the streams and lakes which receive the urban runoff due to increased turbidity and the presence of floating materials, should be added to the direct costs associated with urban runoff. These market and nonmarket costs to the citizens of Austin are offset by the potential benefits which can be experienced through the control of the pollutants in urban runoff. A rigorous cost/benefit analysis would have to encompass all estimated market and nonmarket costs of urban runoff to the City of Austin to balance against the cost of the structural control devices such as the Woodhollow storm water retention basin.

The nonstructural control alternative evaluated by the Austin NURP project was the use of impervious cover limitations on new construction. The concept of this control method is to limit the total mass of pollutants washed from urbanized areas into receiving waters. Implementation of this concept involves requiring urban development to adhere to a maximum limitation on impervious cover including roof areas, streets, and parking lots. In this study, two levels of urban land use impervious cover characteristic of Austin were evaluated; the Rollingwood area which represented low density residential land use and the Northwest Austin site which represented moderate density residential land use. In the context of single-family dwellings, a limitation on impervious cover will translate directly to a lower density of residences per unit area. When multi-family dwellings such as condominiums and apartments are considered, it is possible to limit impervious cover at higher occupancy rates per acre by leaving significant areas of unpaved open space in urban developments to capture rainfall and reduce runoff.

The water quality benefits accruing to use of limitations on impervious cover as a nonstructural control are identical to those previously described for the structural control alternative. Both the total volume of runoff and the mass of pollutants washed from the residential watersheds evaluated during this study were directly related to the area of impervious cover in each watershed. An additional benefit of the nonstructural control alternative was the reduction in quantity of runoff and the attenuation of peak runoff volumes associated with the watershed with lower impervious cover. These effects lessen the potential for flooding of the receiving stream downstream of the watershed and also reduce stream velocities which should decrease erosion of stream beds and banks. As discussed above for the structural control alternative, quantification of the water quality benefits associated with control of impervious cover was not possible, given the available data base.

The costs of utilizing limitations on impervious cover to control urban runoff are much more difficult to estimate than the costs of structural control. If the assumption is made that limitations on impervious cover equate directly to less intensive land use and lower maximum population in a particular watershed, which is generally the case, then the primary components of such costs can be identified. Decreased density of land use will generally result in higher per capita costs for services such as roads, sewers, electric power, and water lines, inasmuch as the same area must be served but there are fewer people and connections to help pay the costs. These costs are offset however by the lower total capacity of each type of service which must be supplied, for example, smaller water mains. It can be expected that lower density land use may also result in decreased property tax revenue, although this may not always be the case inasmuch as in many cases the residential land use in low density areas will be made up of residences with values far above the mean or median cost homes. Additionally, construction of multiple-family units, such as apartments and condominiums in the same area, may maintain high property values and taxes while still meeting the limitations on impervious cover.

It can be seen from these examples that the direct costs of implementation of impervious cover limitations to control urban runoff cannot be estimated without making a number of qualifying assumptions. Because of the wide range of potential approaches to meeting such limitations in the Austin area, no estimate could be made of the cost of such a nonstructural alternative. When time and money permits, the best approach to quantifying such costs would probably be to select two already developed residential watersheds with significant differences in impervious cover, such as the two utilized in this study, and then obtain through tax and utility records the necessary information to prepare such a cost analysis. It would have to be recognized, however, that this type of analysis would be limited in scope since it does not consider all of the options that could be used to limit impervious cover in a new development for the expressed purpose of runoff control.

NURP PUBLIC OPINION SURVEY

A public opinion survey was conducted in August 1982 and consisted of 1000 telephone interviews of registered voters within the Austin city limits. This high number of interviews allowed for a plus or minus three percent accuracy in the survey results at 95 percent confidence limits.

The survey was designed to answer some specific questions about the public's perception of water quality in the Austin area. Eleven questions in four major areas: general environmental concern, water quality issues, responsibility and resource allocation, and usage provided the basis for the survey questionnaire. The canvassing was conducted by Opinion Analysts, Inc. of Austin, Texas, and all interviews were conducted by a trained, professional interviewing staff.

The following is a summary of the conclusions presented in the document entitled "Nationwide Urban Runoff Program: Public Attitude Survey" dated August 1982. (The document is an addendum to this report.)

(1) The water quality problem was considered serious or somewhat of a problem by a majority of the registered voters for both surface water (68 percent) and groundwater (59 percent).

(2) By a 2:1 margin, the respondents felt that "development/construction was the major source of pollution and contributed "a lot" to the problem.

(3) The main types of pollution were identified as either bacteria or nutrients (algae/weeds).

(4) By a greater than 2:1 margin, the respondents felt that legal restrictions were preferable to either voluntary compliance or tax and monetary incentives.

(5) Approximately 2/3 of the registered voters would be willing to pay $0.50 to $1.00 per month for water pollution cleanup.

(6) Three to five times as many respondents felt that the polluters should pay with regard to pollution caused by septic systems and development/construction. Pollution from streets was seen to be the main responsibility of the utility users (general public).

(7) Of the water bodies listed, all were perceived by a majority to be either very or somewhat polluted. The cleanest was perceived to be Lake Austin, the most polluted was perceived to be Shoal Creek.

(8) Seventy-two percent of the registered voters surveyed use Austin's lakes and creeks to some degree. The one used most often was Lake Travis, followed by Lake Austin. Over half the people either swim or boat, with the main recreational activity being swimming by a large margin.

Of interest in the data dealing with recreational activity was the indication that such a large percentage (56 percent) of the respondents either swim, ski, or fish. Forty-four percent of the respondents participate in some form of contact recreation (36 percent swim and eight percent ski). Twelve percent of the respondents fish in area water bodies, and as such, would have aquatic life concerns.

Even though the vast majority of answers were consistent with existing water quality data, there were some discrepancies. There were several areas where the respondents seemed misinformed. (1) Development/construction, in that it was rated as a major problem, yet sedimentation was not perceived as the problem that it is in Austin. (2) Industrial waste discharge was seen as more of a problem than the situation indicates, and this was also true of chemical (toxic) pollution. (3) Barton Springs ranked too high in pollution in terms of what the data warrant, but this is understandable in light of recent newspaper articles about pollution in the Barton Creek area.

CONCLUSIONS

The following can be concluded from the data obtained during the Austin NURP study:

(1) The difference in the pollutant mass loads from the two test watersheds, Northwest Austin (medium-density residential) and Rollingwood (low-density residential) were quite distinct. These storm water runoff data indicate a definite trend toward higher runoff coefficients with an increase in impervious cover. Therefore, the Northwest Austin site produced runoff pollutant loads per acre of surface on the order of 5 to 10 times greater than those generated from the Rollingwood watershed.

(2) Limited storm water quality data collected from the sparsely developed control watershed (Turkey Creek) indicated that substantially lower pollutant loads are generated from undeveloped areas than are produced from runoff associated with low-to-medium density residential development with the natural hydrologic characteristics found in north and west Austin. The quantity of runoff per acre of land area at Turkey Creek was significantly lower than that measured at the other two sites. In addition, peak flow rates at Turkey Creek were significantly attenuated compared to those associated with similar rainfall intensities at the other two sites, and the runoff recession often continued for a number of days after a rainfall event due to storage and release of the water by limestone strata in this area.

(3) Data collected from the Northwest Austin and Rollingwood residential watersheds showed that the concentrations of the pollutants measured in the urban runoff were either variable depending on the type of pollutant, or were not statistically different. It was found that the greater volume of runoff from the higher density residential watershed (Northwest Austin) tends to dilute the greater mass of pollutants washed from this watershed to concentration levels similar to those observed for the low-density residential area. Limited storm water quality data for the

undeveloped Turkey Creek watershed indicate that, of those parameters examined, nitrate, phosphorus, and fecal coliforms were lower than those measured at the urbanized sites. The concentrations of the other parameters were not significantly lower. It can be concluded from these data that the primary factor determining the quality of pollutants in storm water runoff from the NURP watersheds, with the exception of those pollutants contributed directly by human and animal activities such as nitrates, phosphorus, and coliforms, is the relative area of impervious cover in a particular drainage area.

(4) Significant levels of toxic pollutants were not found in either the storm water runoff samples collected at the Northwest Austin and Rollingwood sites or the samples collected from the water column in Town Lake and Lake Austin. Moreover, other than the presence of measurable quantities of lead and zinc, only trace levels of insecticides and defoliants were present in the storm water runoff samples collected from the two test watersheds.

(5) Storm event oriented water quality sampling on Town Lake and Lake Austin indicated that the short-term effects of runoff-generated pollutants (BOD_5, NH_3, TSS, PO_4, fecal coliforms) on receiving water quality can be significant, although chronic water quality impacts were not apparent. Austin NURP monitoring and analysis activities on Town Lake and Lake Austin have produced data which quantify water quality effects that support present concerns regarding the impact of urban runoff on the recreational uses of the lakes. Elevated coliform levels were observed in the lakes in association with runoff periods, and at times exceeded water quality standards for recreational use. In addition, the presence of floatables (i.e., oil and grease and refuse) were observed in the tributaries to the lakes at levels which discourage recreational use. Nevertheless, these data do not suggest that urban runoff has reduced the usefulness of Town Lake or Lake Austin as a potable water source to the City of Austin. Metals, for example, which were present at elevated levels in storm water runoff, were not detected at hazardous concentrations in the water column of the two lakes.

However, survey data indicated that lake bottom sediment samples did contain environmentally persistent constituents (DDT and its breakdown products and metals) which were deposited over many years, even though ambient water concentrations for these same constituents were negligible.

(6) Although the use of the chlorinated hydrocarbon pesticide, DDT, has been outlawed for over a decade, it is still present in the sediments of Town Lake and Lake Austin. The principal source of this apparent pollutant load, in this instance, can be related to translocation of the DDT complex by adsorption on sediments which move from adjacent lake bottoms during major storm events. The dynamics of chlorinated hydrocarbon translocation and bioaccumulation in the aquatic environment, although complex, are susceptible to study. Approaches to the estimation of rates of input, decay, and translocation can be developed and assessed by continued analysis of such environmental samples as lake bottom sediments and fishes.

(7) The concentrations of metals and chlorinated hydrocarbon pesticides and PCBs measured in the tissues of fish samples collected from both Town Lake and Lake Austin were not at a level considered hazardous to public health. However, since DDT and its breakdown products are carcinogenic, further study into the distribution of this pollutant in the sediments and biota of Lake Austin and Town Lake is recommended.

(8) The total chemical cost associated with the treatment of drinking water was affected by storm water runoff and subsequent lake water quality. There was an apparent increase in water treatment chemical costs for the production of drinking water which correlated with runoff events when the cumulative rainfall volume was greater than one inch. Part of this increased cost is the result of increases in hardness and alkalinity caused by nonurban storm runoff, however, the bulk of the chemical cost increment is associated with increased consumption of activated carbon and chlorine, for controlling taste and odor, and higher bacteria levels. This incremental increase in cost of treatment is

minimal, however, based on the magnitude of the difference and the small percentage of time during the year that the situation occurs.

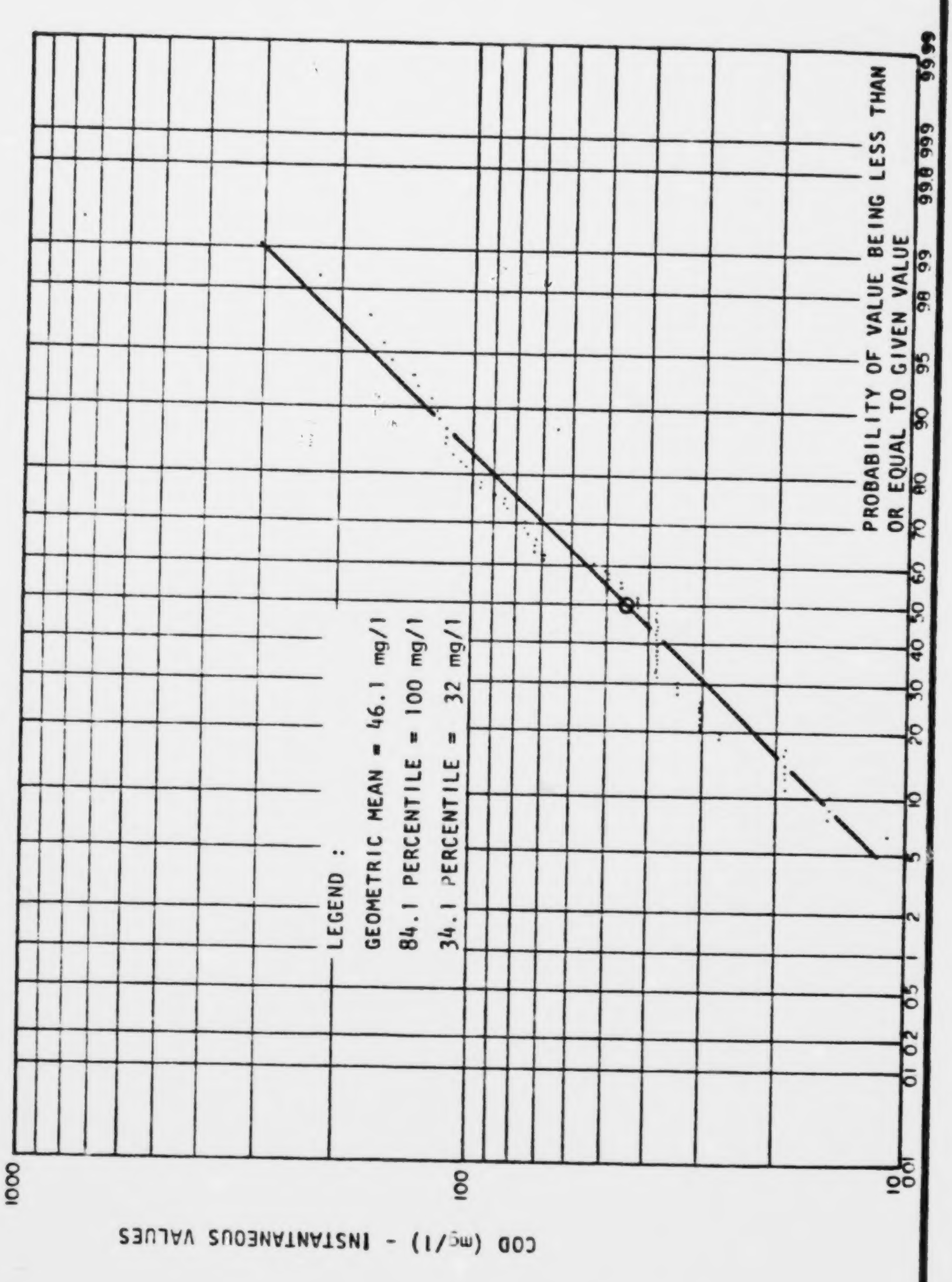
(9) The effects of urban storm water runoff on Town Lake appear to be more significant than Lake Austin, specifically with regard to bacteria in the water column. Differences between the lakes, with regard to other parameters in the water column are inconclusive. Town Lake also appears to be more polluted than Lake Austin in the following areas: bottom sediment analysis (lead, zinc, and DDT) and fish tissue analysis (lead, copper, and DDT).

(10) The public opinion survey indicated that there is a strong interest and generally accurate awareness of water quality issues among the registered voters of Austin. Water pollution was considered to be a problem by the majority of registered voters, and all water bodies listed were considered polluted, especially the most urbanized. Most of the voters use the lakes and creeks to some degree, especially Lake Travis and Lake Austin. A majority of the respondents utilize the various water bodies for some form of contact recreation, and thus the existing contact recreation standards and criteria are appropriate.

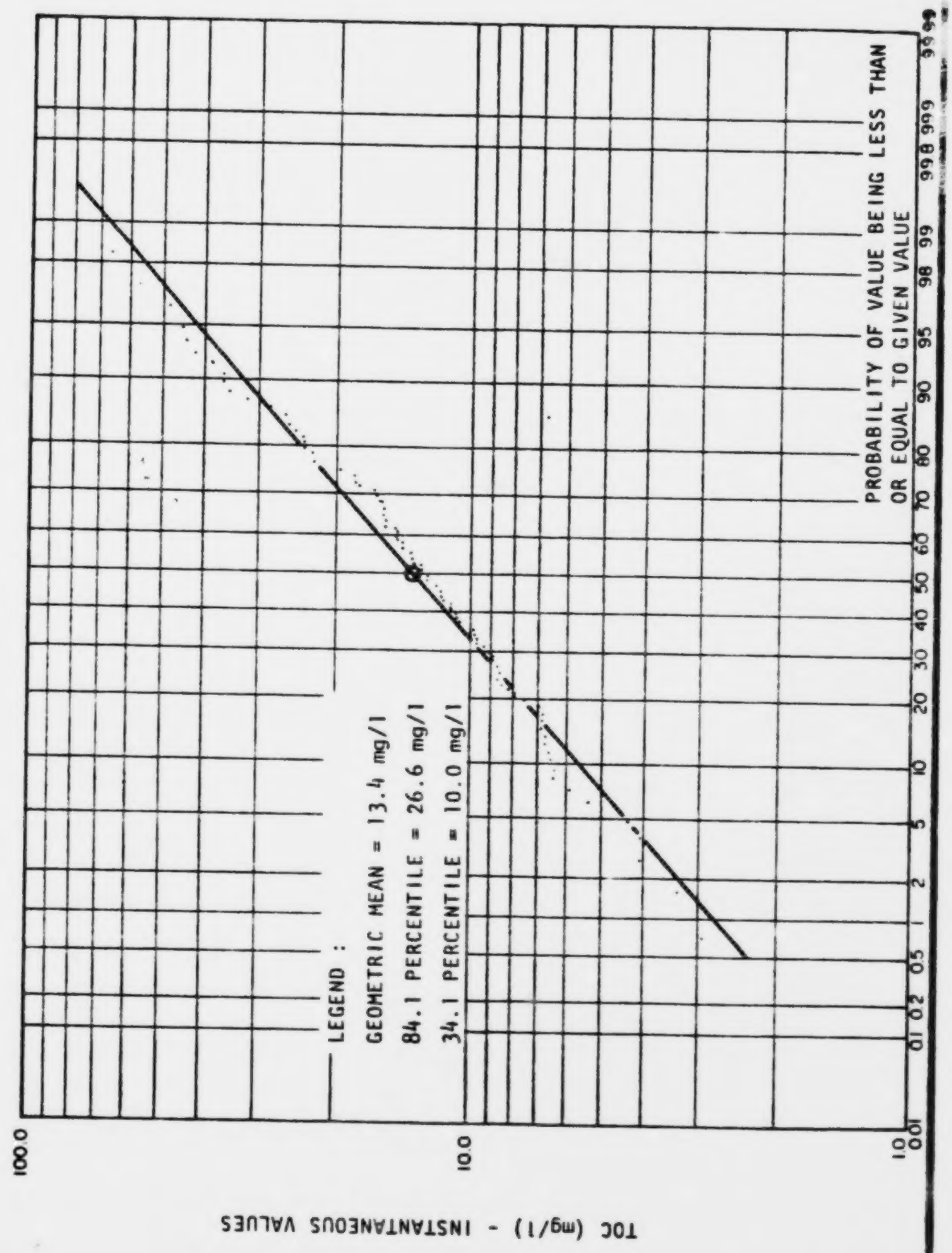
APPENDIX A

LOG NORMAL PROBABILITY DISTRIBUTIONS FOR INSTANTANEOUS CONCENTRATION VALUES ASSOCIATED WITH STORM WATER RUNOFF SAMPLES

NORTHWEST AUSTIN COD



NORTHWEST AUSTIN TOC



NORTHWEST AUSTIN FECAL COLIFORMS

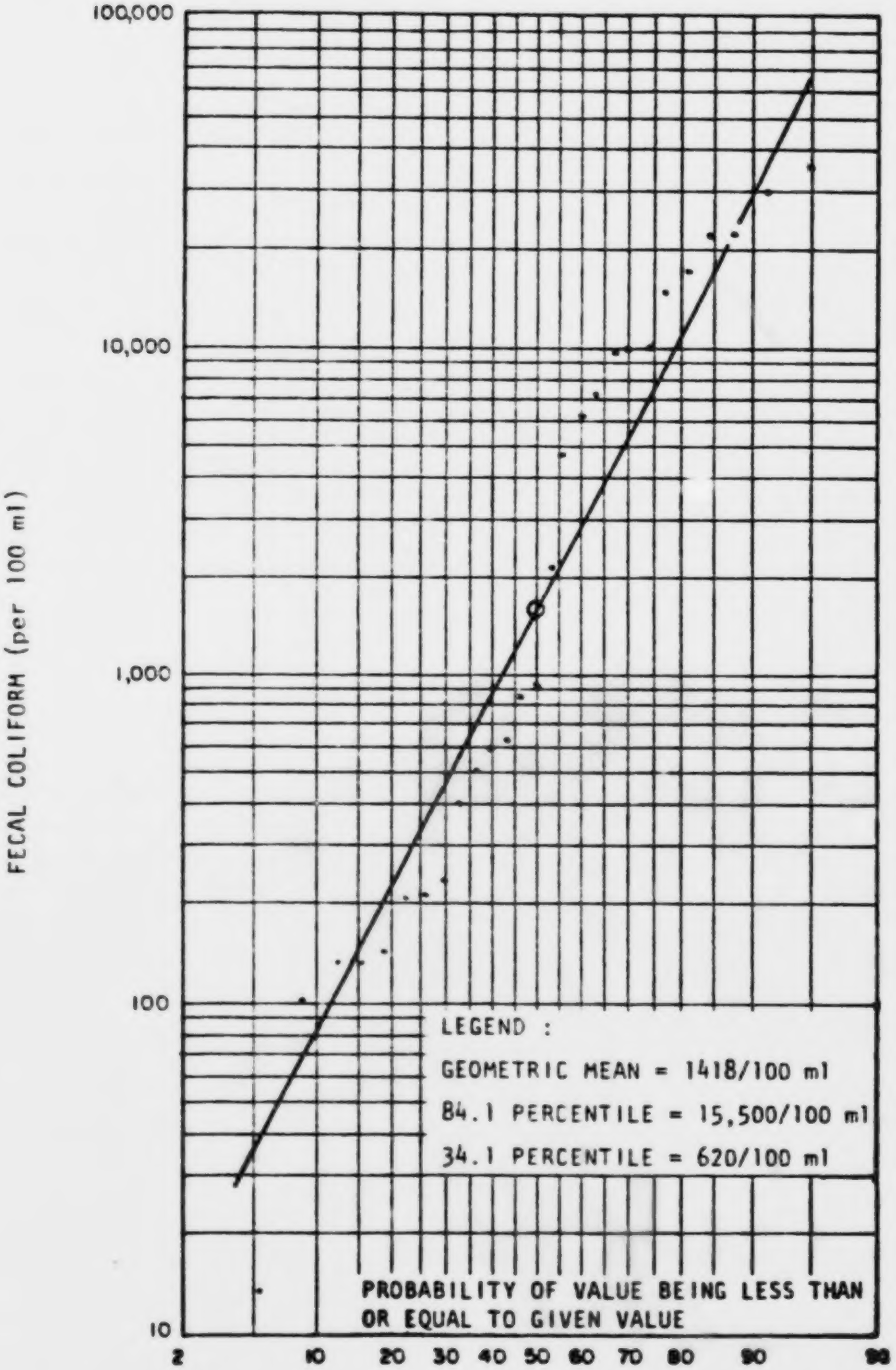
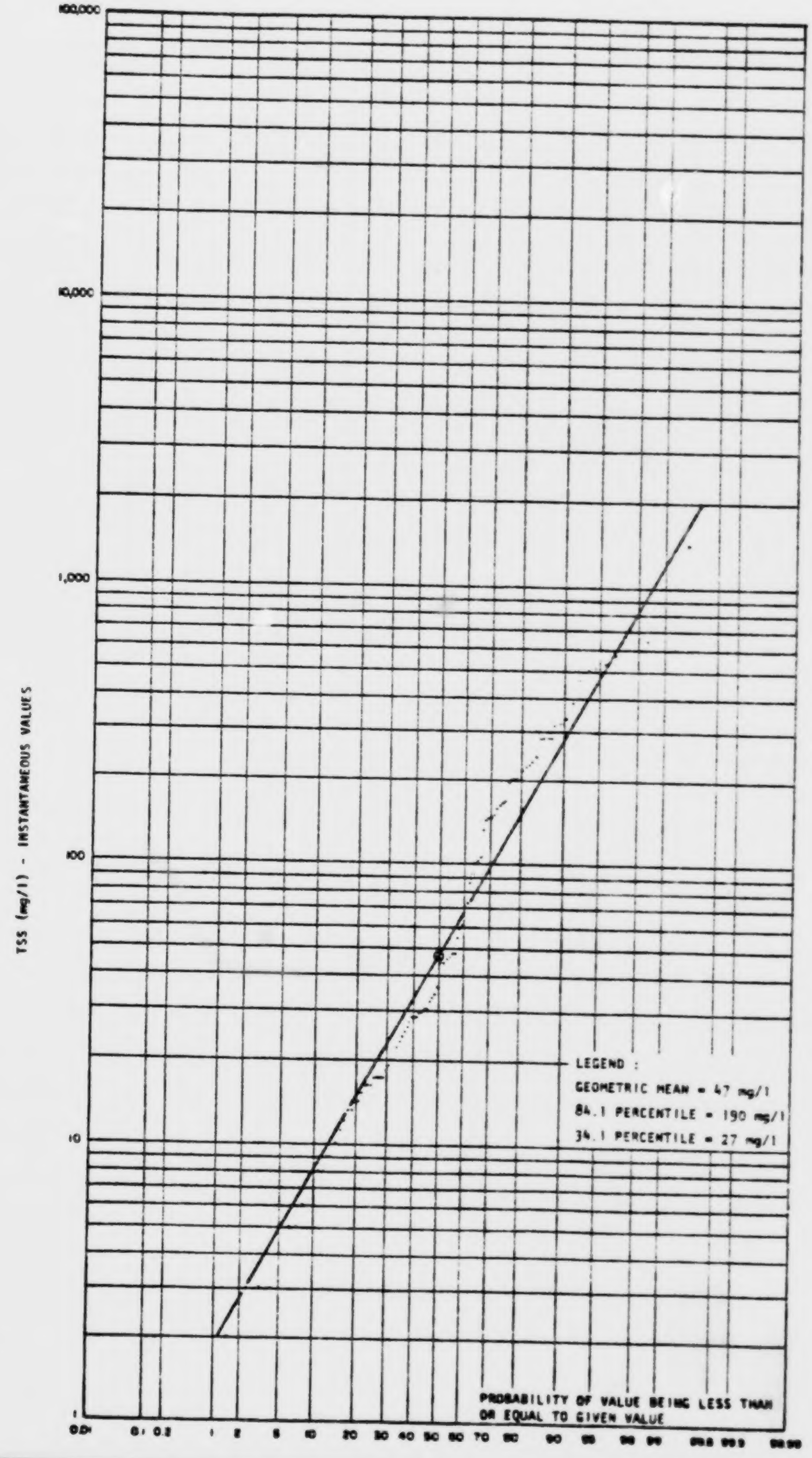


FIGURE A-4

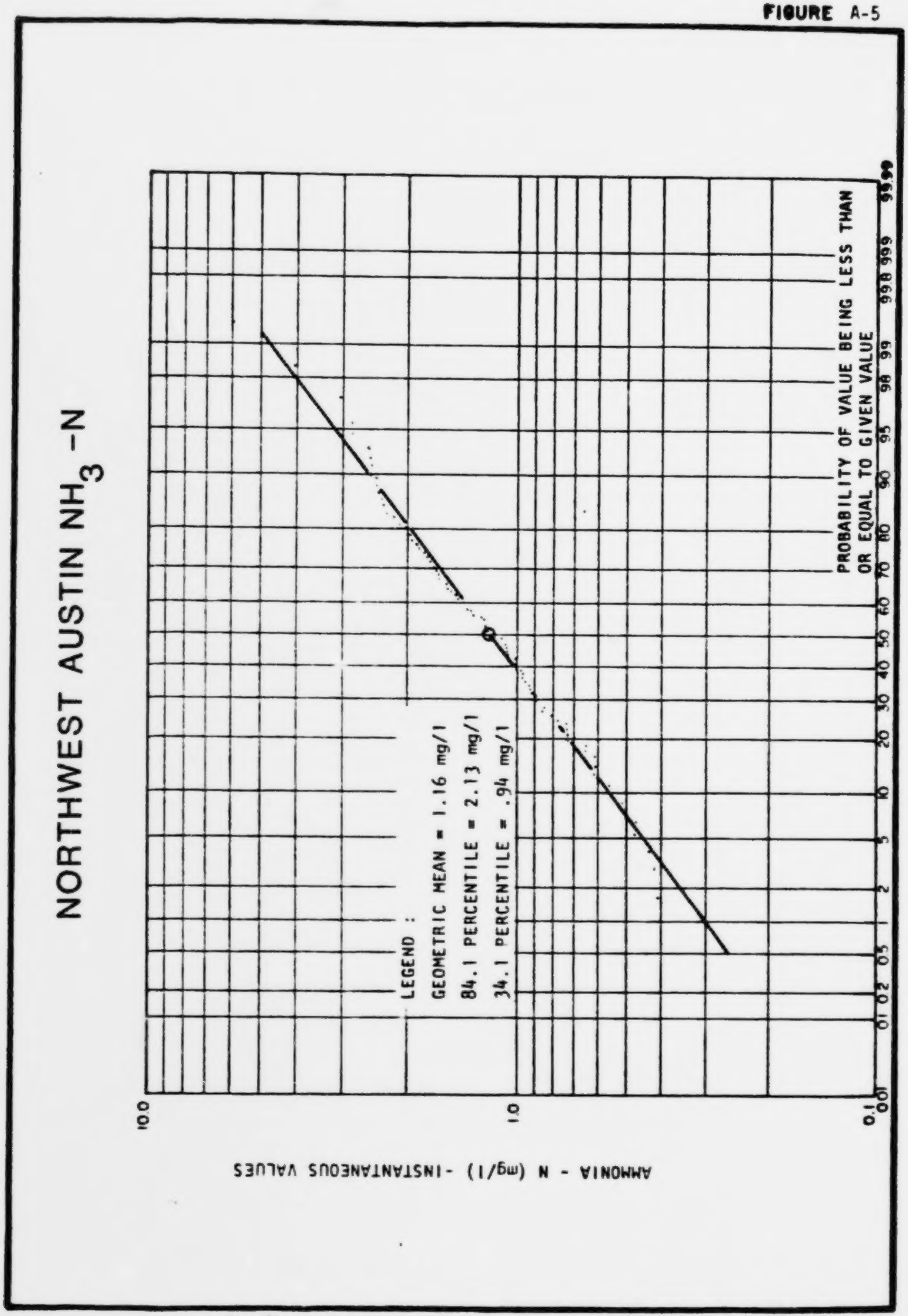
NORTHWEST AUSTIN TSS



LEGEND :
GEOMETRIC MEAN = 47 mg/l
84.1 PERCENTILE = 190 mg/l
34.1 PERCENTILE = 27 mg/l

1[illegible]6

FIGURE A-5


NORTHWEST AUSTIN NH_3 -N
LEGEND :
GEOMETRIC MEAN = 1.16 mg/l
84.1 PERCENTILE = 2.13 mg/l
34.1 PERCENTILE = .94 mg/l
10.0
1.0
0.1
AMMONIA - N (mg/l) -INSTANTANEOUS VALUES
.001
.01
.02
.05
.1
.2
.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.9
99.99
PROBABILITY OF VALUE BEING LESS THAN OR EQUAL TO GIVEN VALUE

NORTHWEST AUSTIN TOTAL P

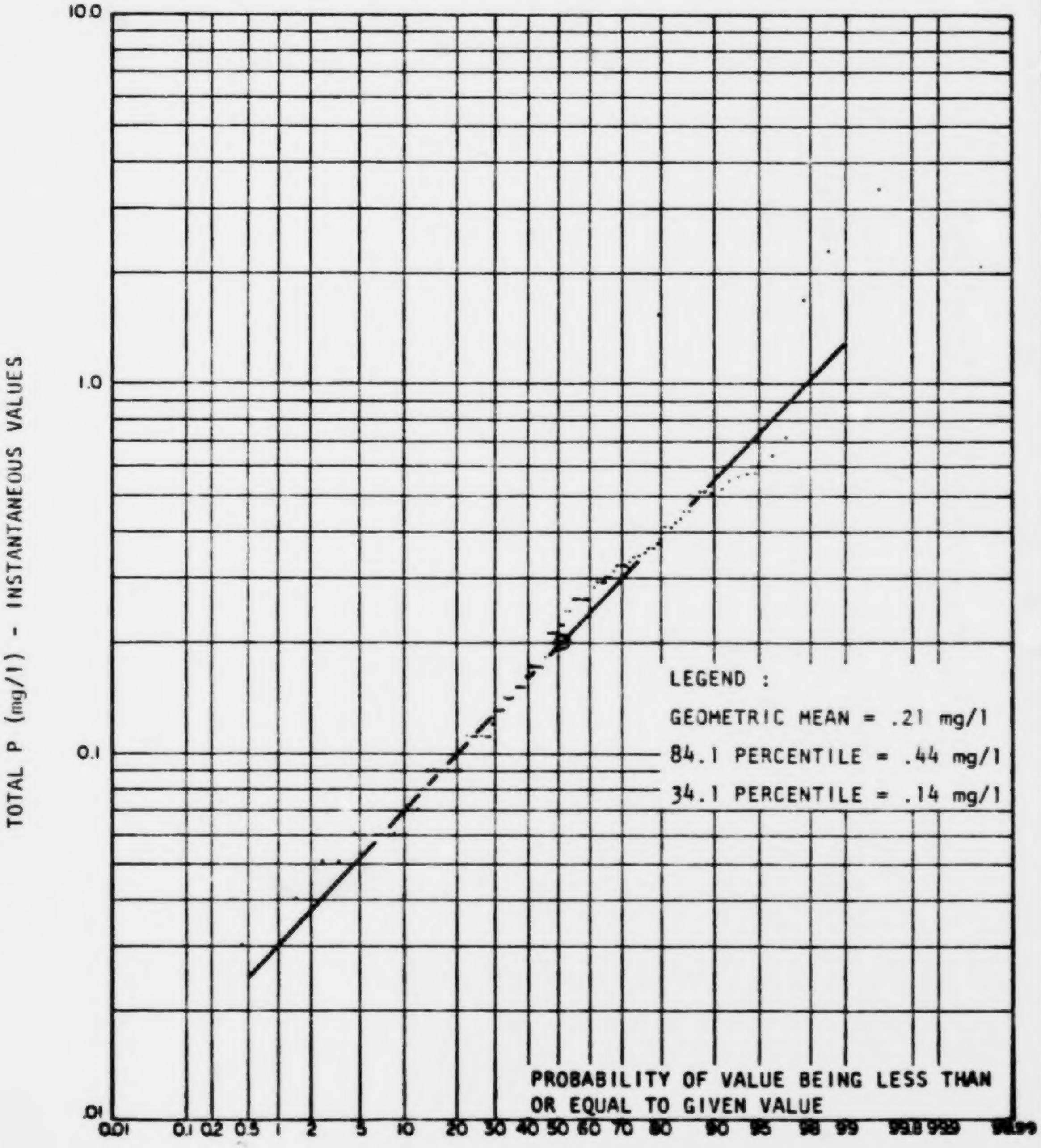
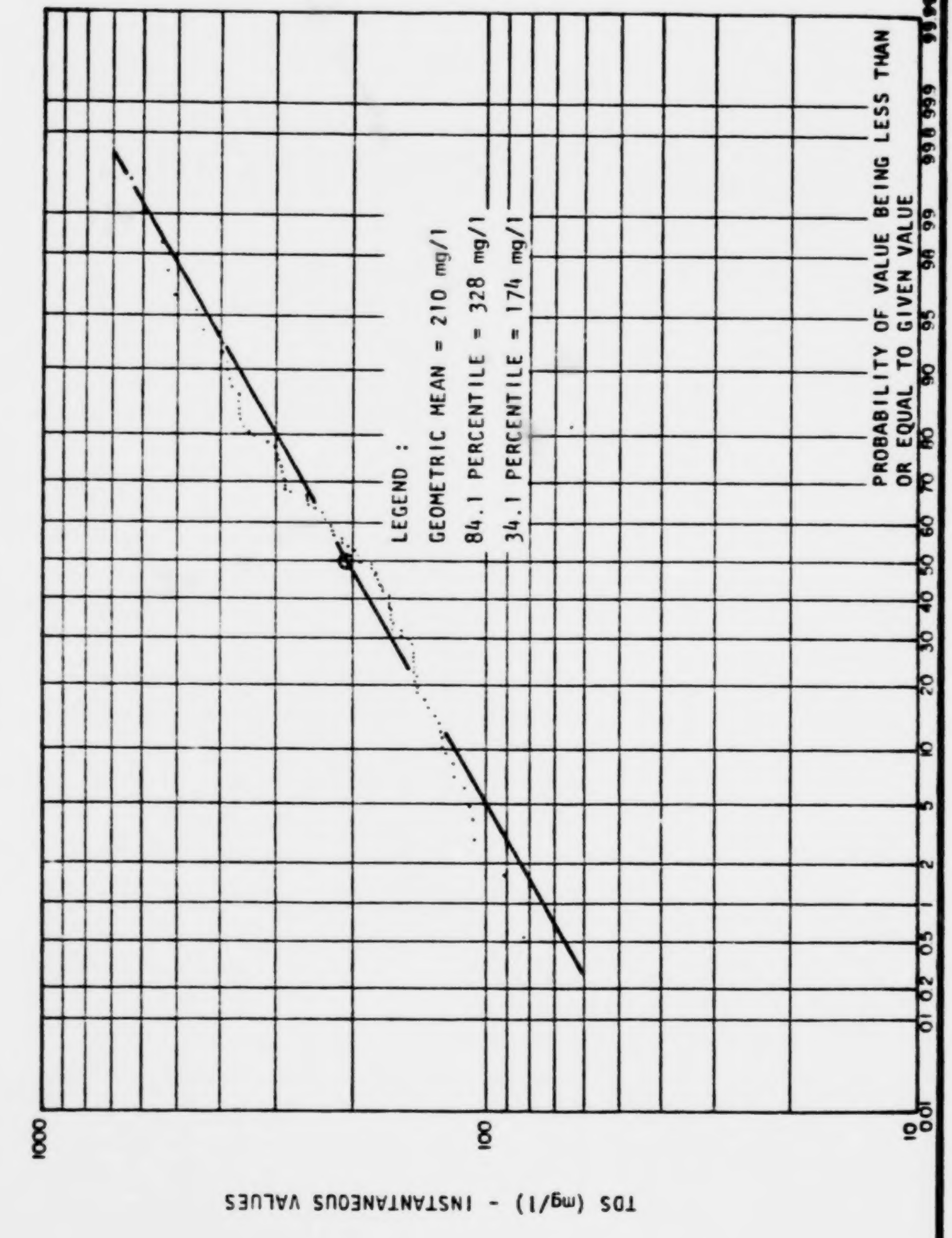


FIGURE A-7

NORTHWEST AUSTIN TDS



NORTHWEST AUSTIN HARDNESS

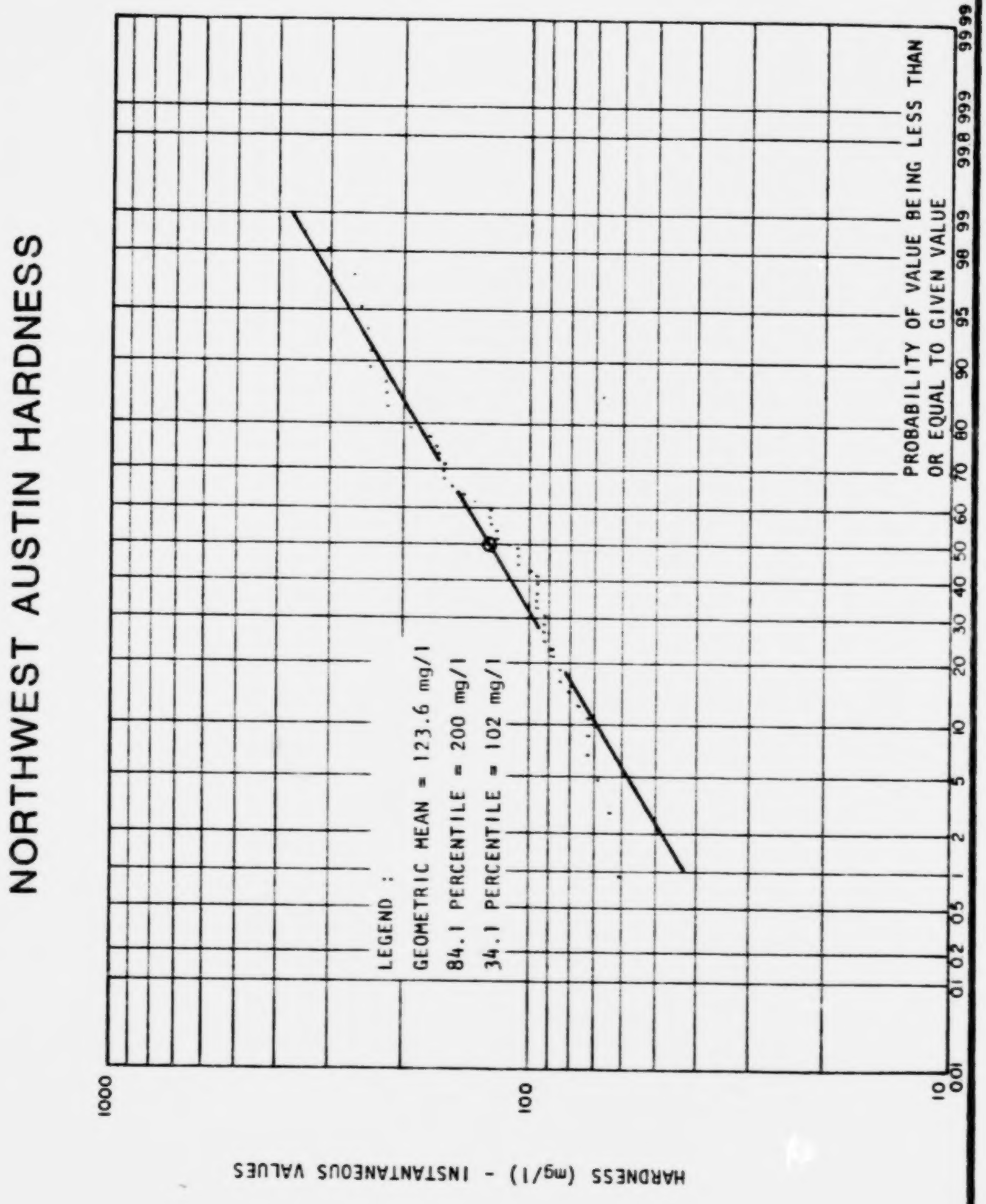


FIGURE A-9

NORTHWEST AUSTIN ALKALINITY

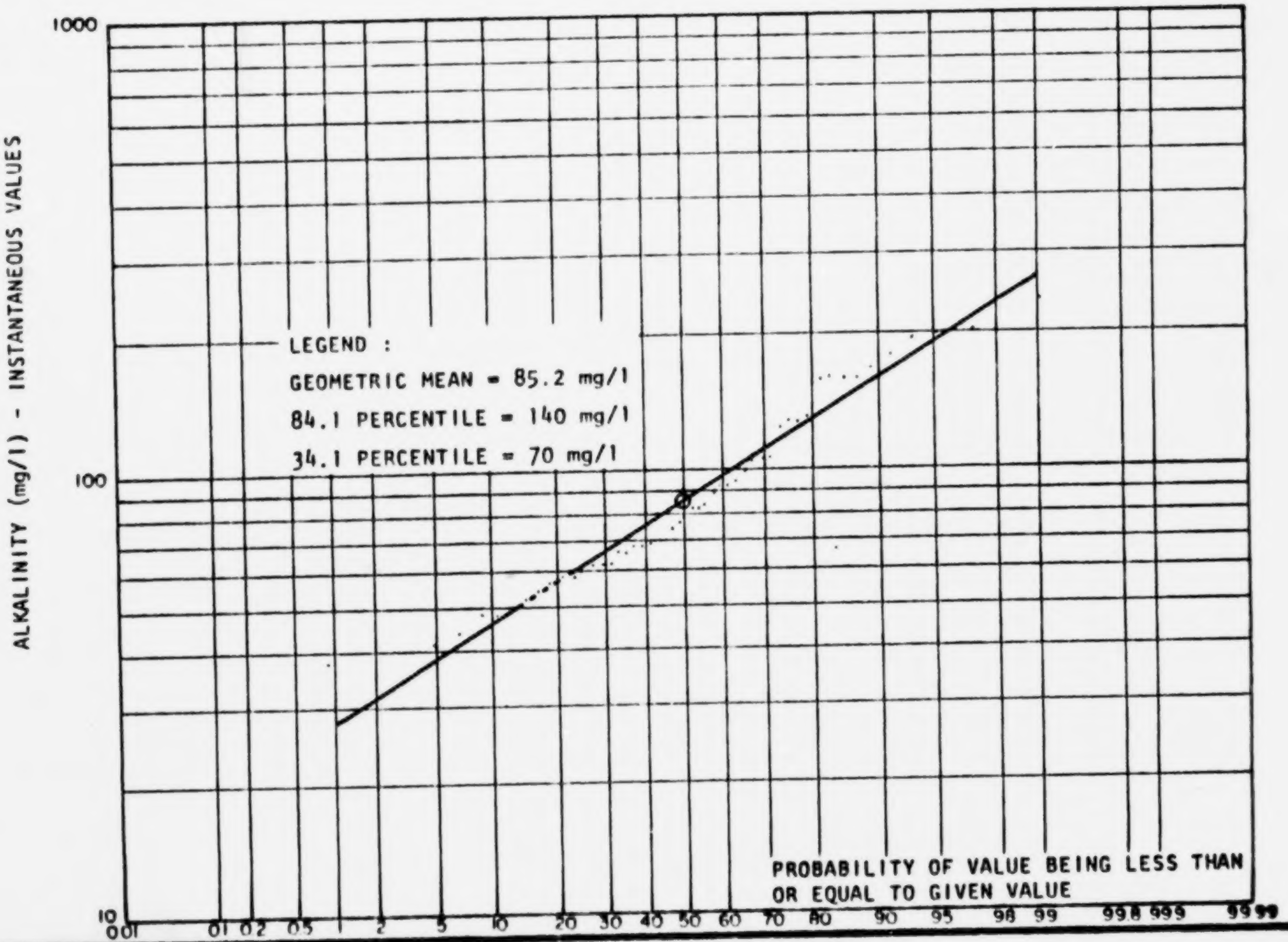


FIGURE A-10

ROLLINGWOOD COD

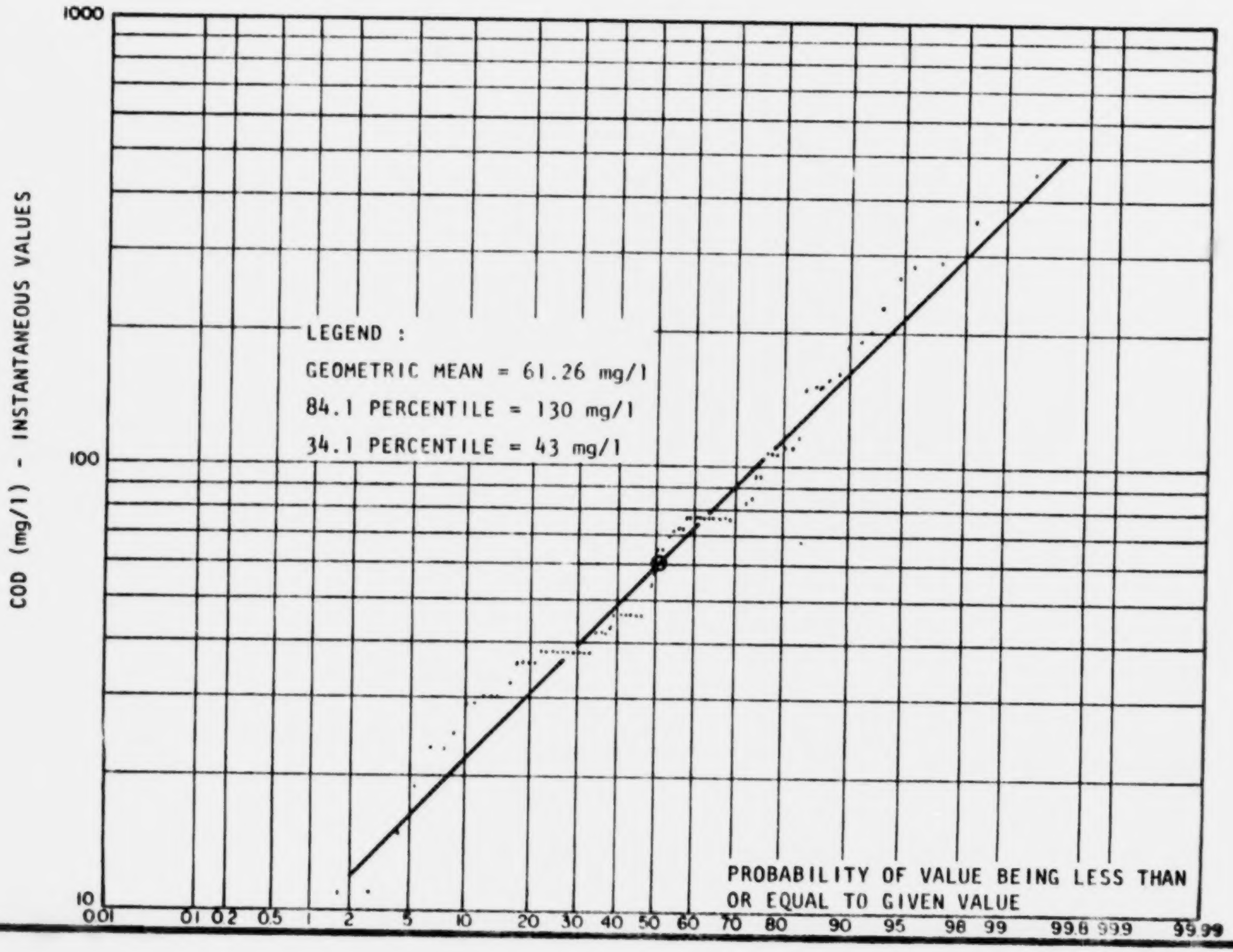


FIGURE A-11

ROLLINGWOOD TOC

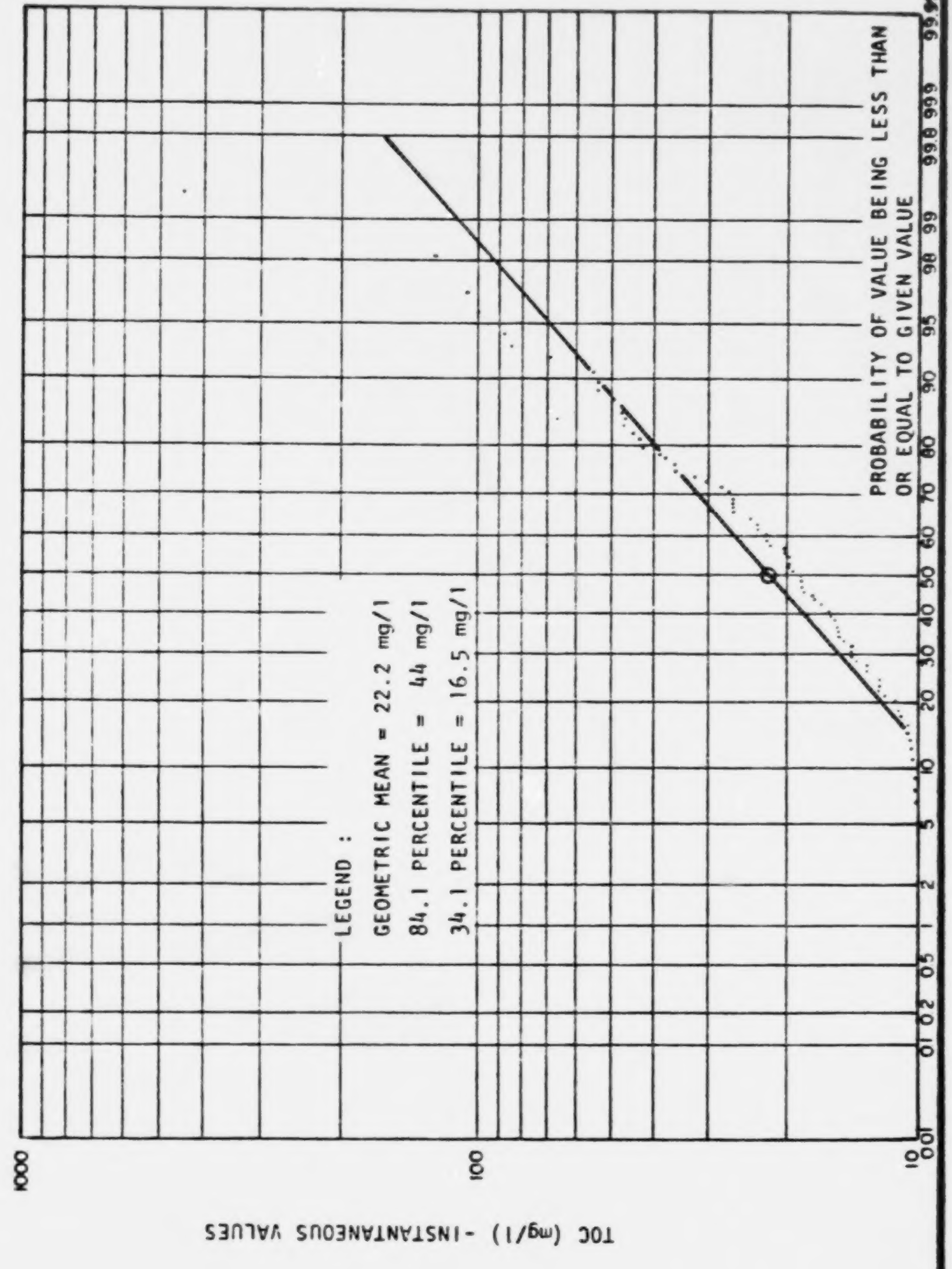


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FIGURE A-12

ROLLINGWOOD FECAL COLIFORMS

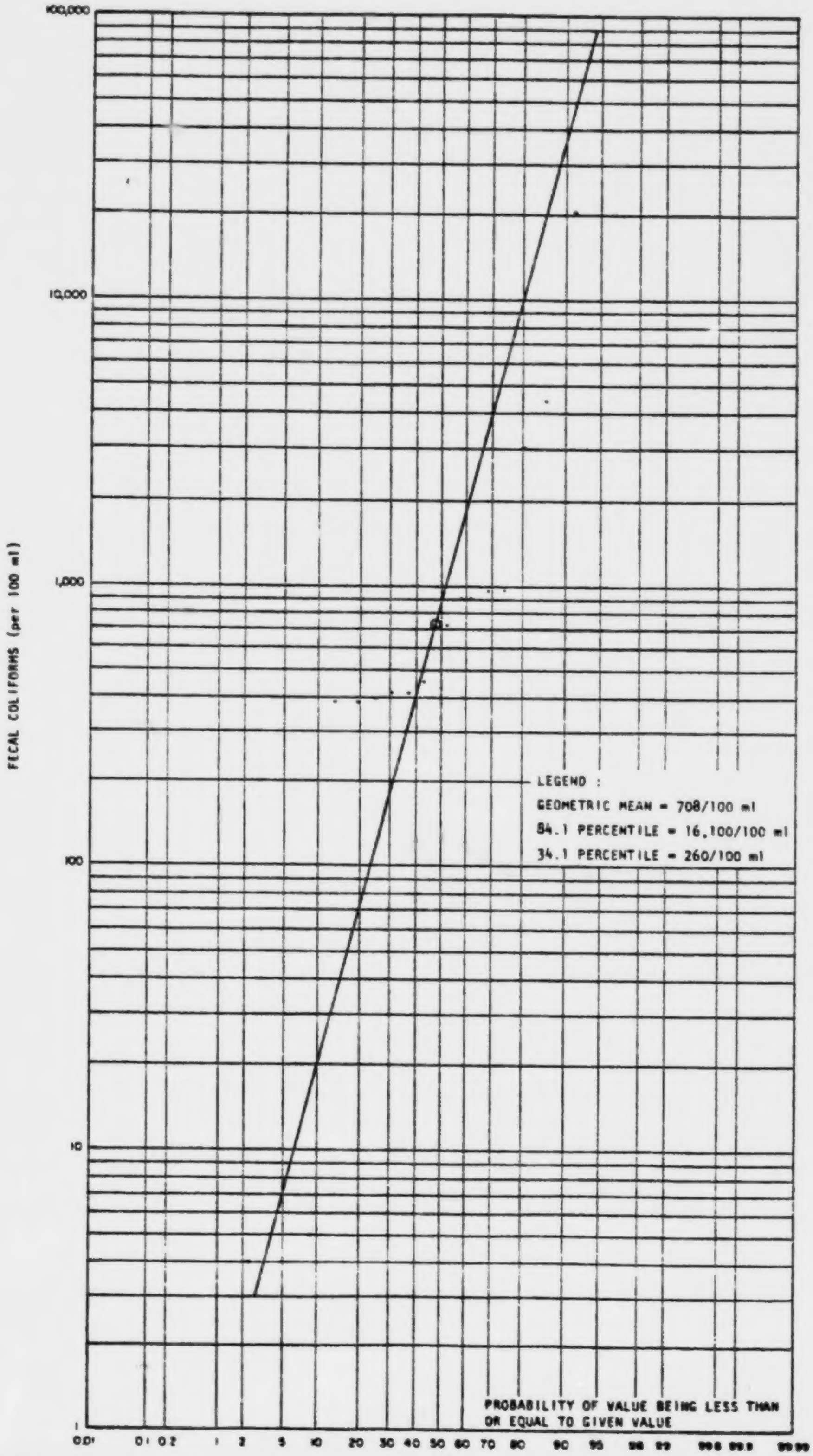
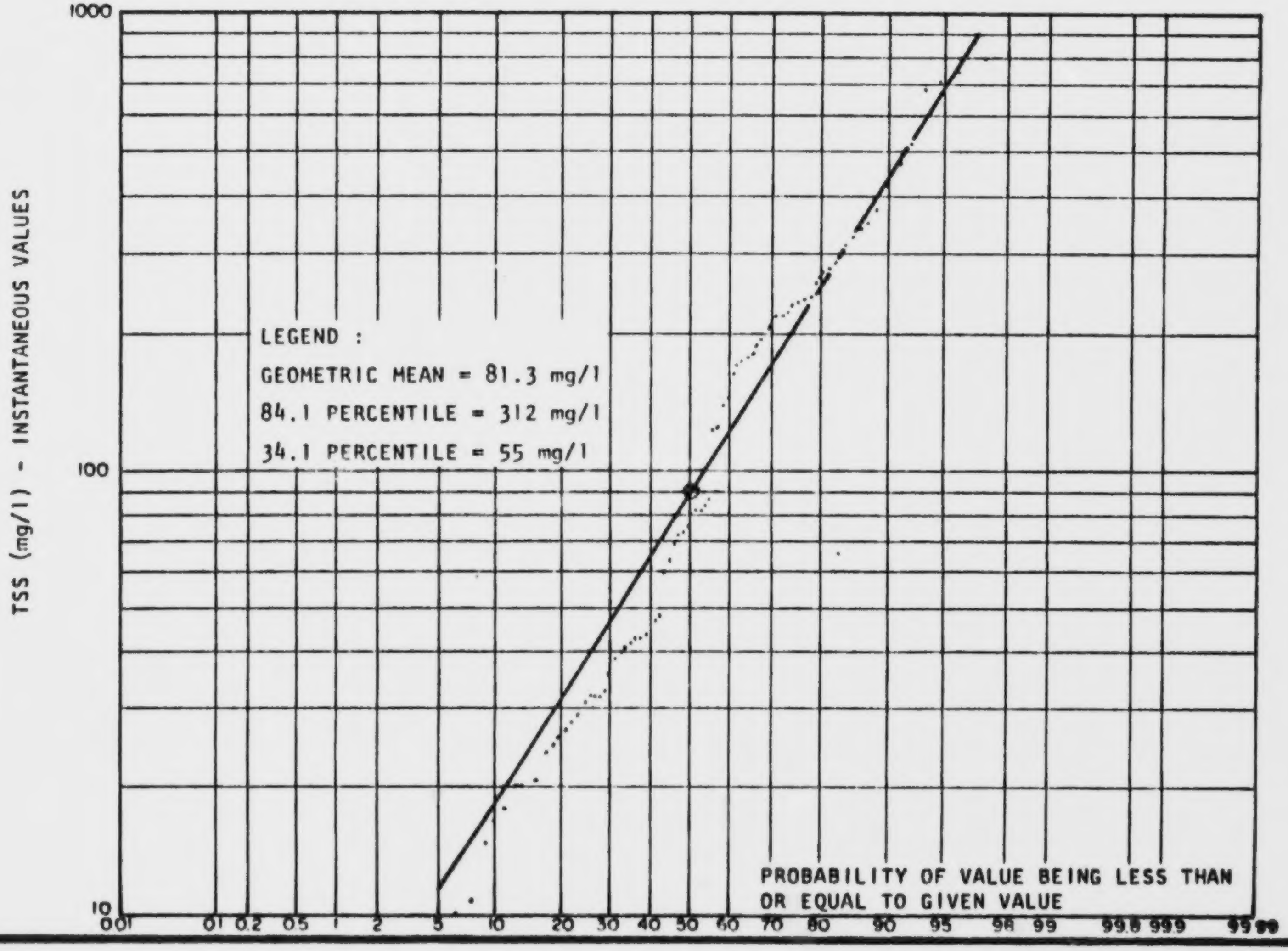
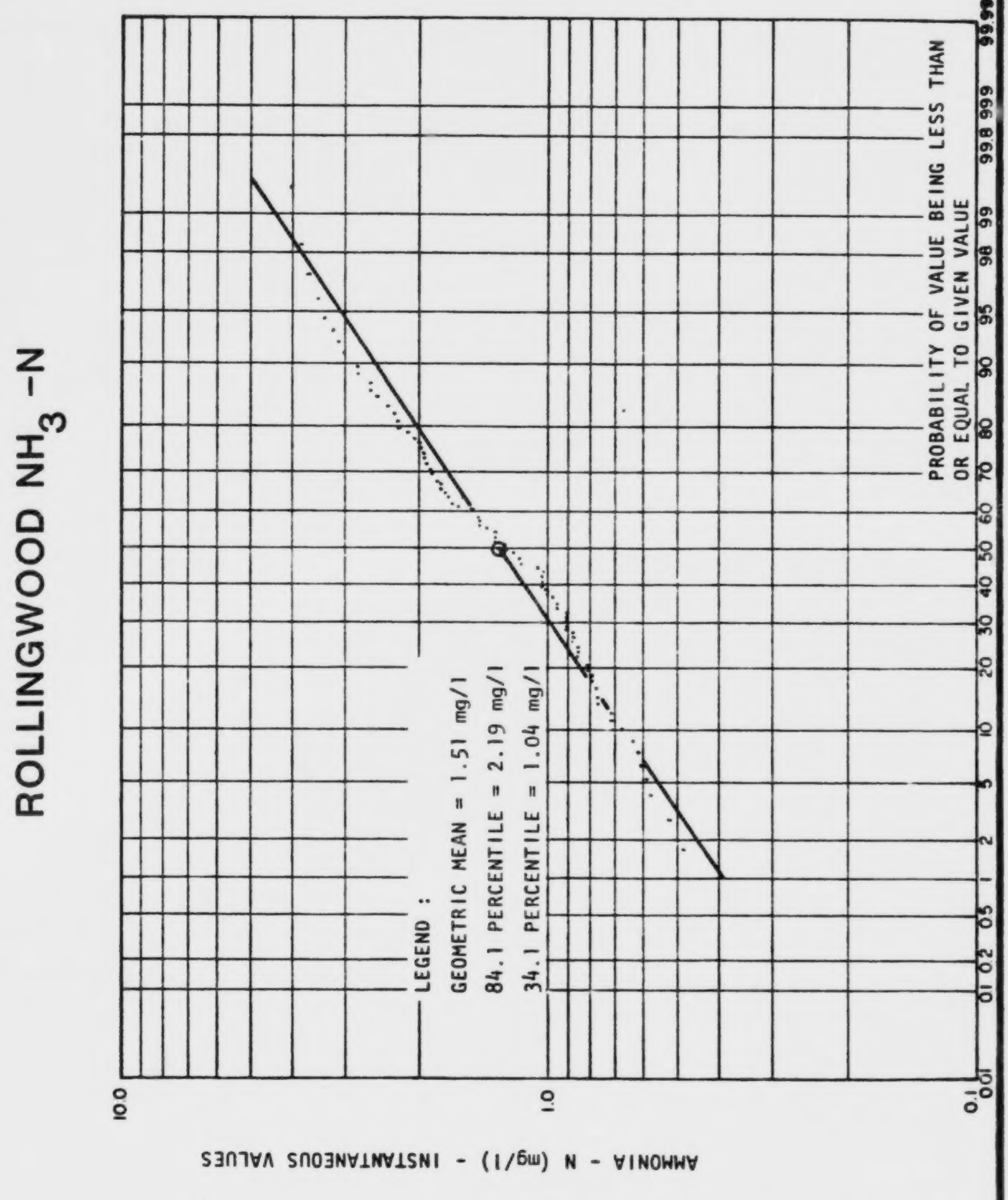


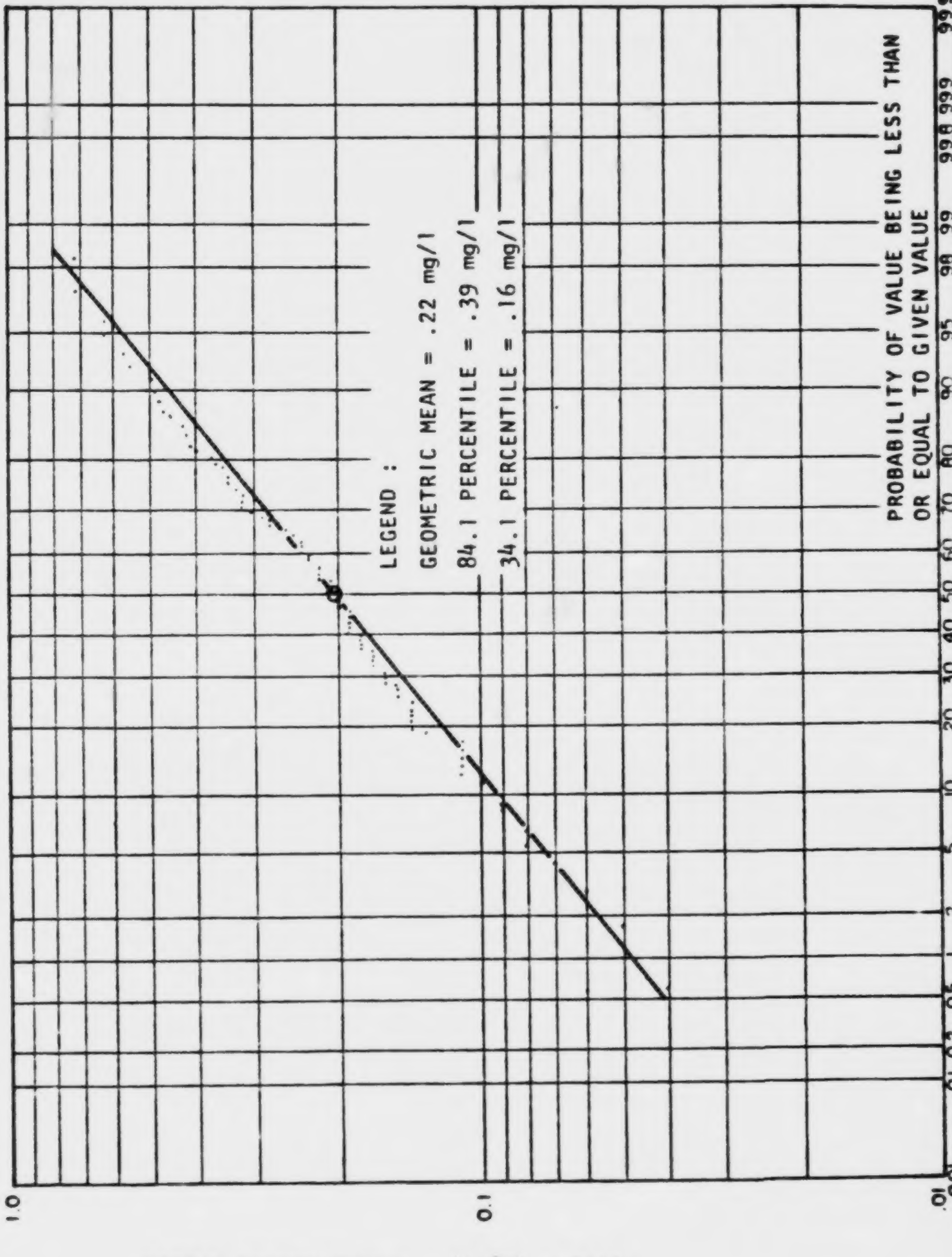
FIGURE A-13

ROLLINGWOOD TSS



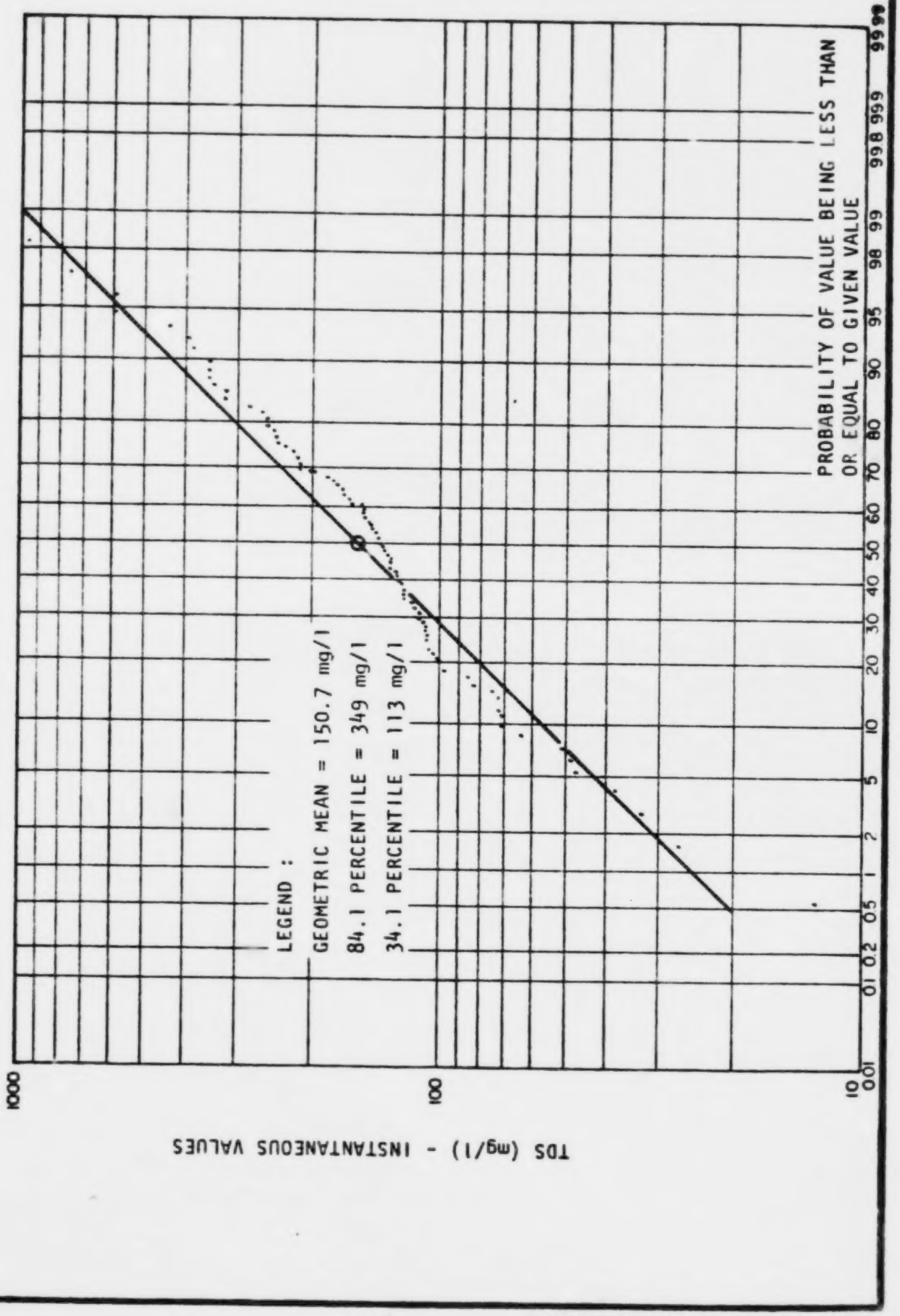

ROLLINGWOOD NH_3 -N
LEGEND :
GEOMETRIC MEAN = 1.51 mg/l
84.1 PERCENTILE = 2.19 mg/l
34.1 PERCENTILE = 1.04 mg/l
10.0
1.0
0.1
AMMONIA - N (mg/l) - INSTANTANEOUS VALUES
0.01
0.1
0.2
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.9
99.99
PROBABILITY OF VALUE BEING LESS THAN OR EQUAL TO GIVEN VALUE

ROLLINGWOOD TOTAL P



207

ROLLINGWOOD TDS



ROLLINGWOOD HARDNESS

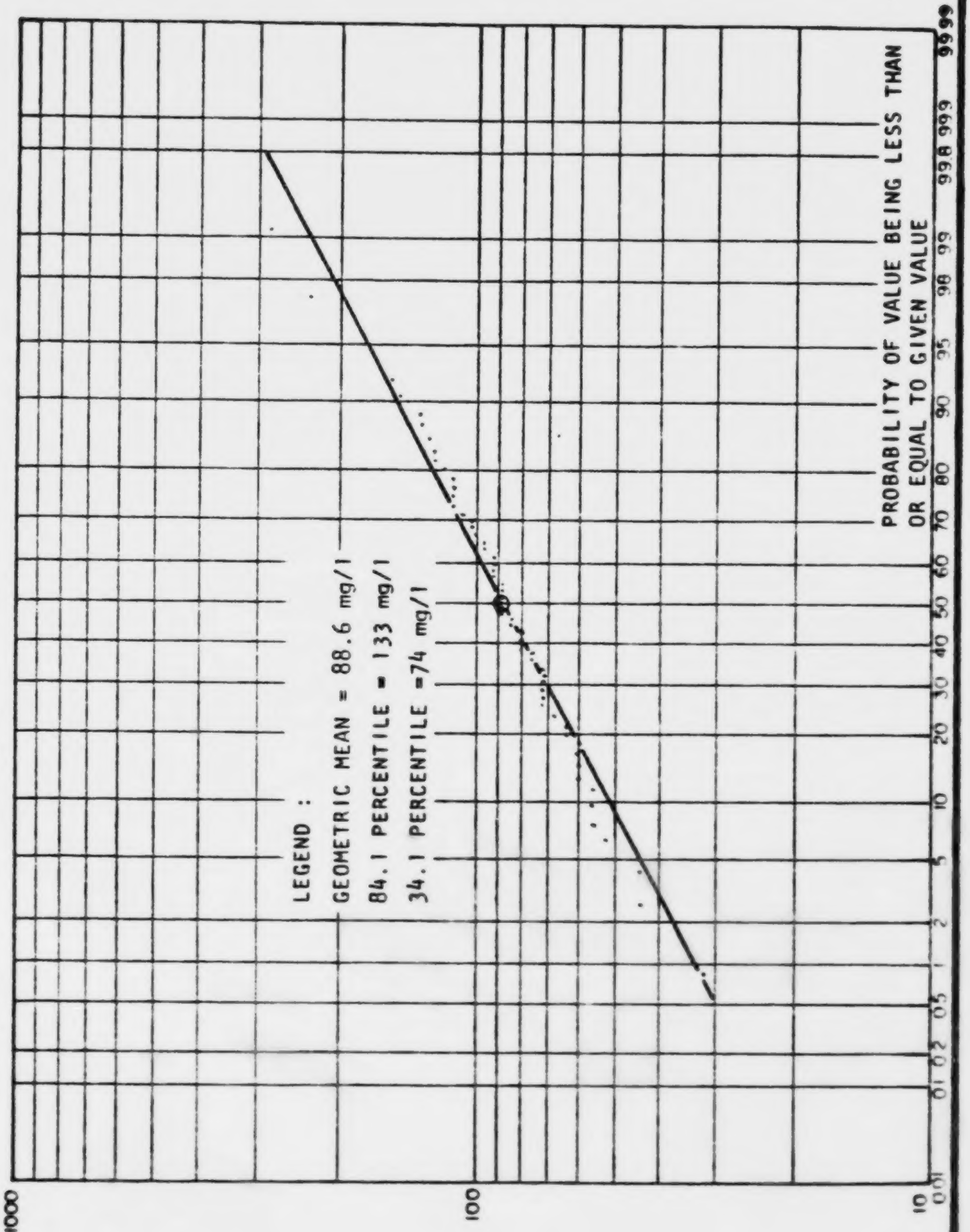
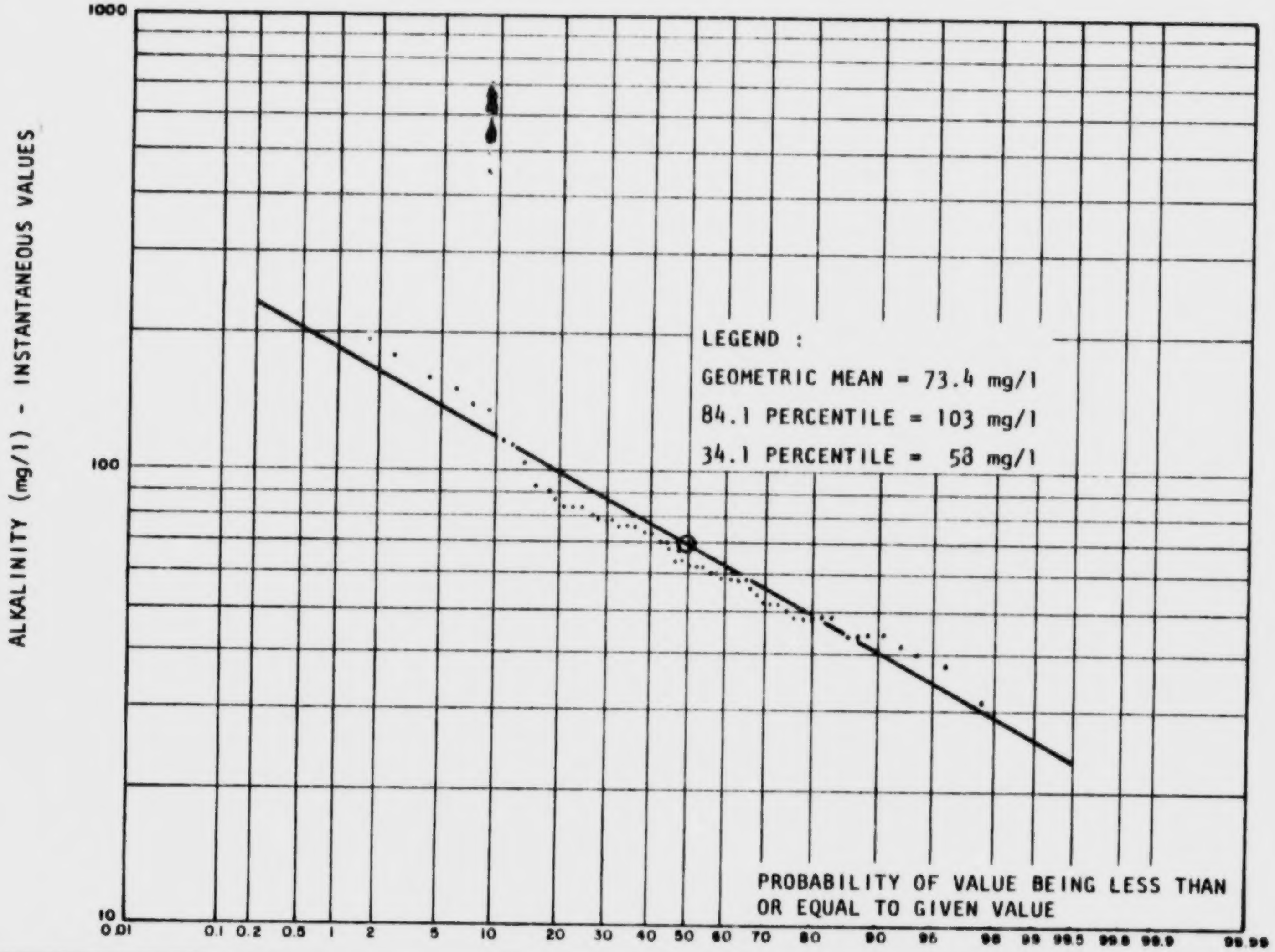


FIGURE A-18

ROLLINGWOOD ALKALINITY



APPENDIX B

STORM EVENT DATA AND HYDROGRAPHS FOR AUSTIN NURP STUDY NORTHWEST AUSTIN (HART LANE), ROLLINGWOOD, AND WOODHOLLOW DAM SITES

DATE : 2/4/81

SITE : HART LANE

EVENT NO. : 01

TABLE B-1

TIME	INST DIS (cfs)	INST POLL CONC (mg/l)					AVG MASS FLUX (lb/hr)					CUM. MASS DISCHARGED (lbs)				
		COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS
1300	0.3	46.	10.9	0.65	—	30.	1.10	0.26	0.02	--	0.72	0.69	0.16	0.01	-0-	0.45
1315	0.3	38.	8.3	0.93	—	28.	2.28	0.50	0.05	—	1.68	1.64	0.37	0.03	—	1.15
1330	0.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1350	0.1	38.	8.5	0.47	—	24.	0.61	0.13	0.02	—	0.38	2.02	0.45	0.04	—	1.39
1405	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1430	0.02	38.	10.2	0.73	—	14.	0.38	0.10	0.02	—	0.14	2.21	0.50	0.05	—	1.46
2230	0.8	8.	6.4	0.47	—	47.	0.50	0.39	0.03	—	2.90	3.53	1.55	0.13	—	9.20

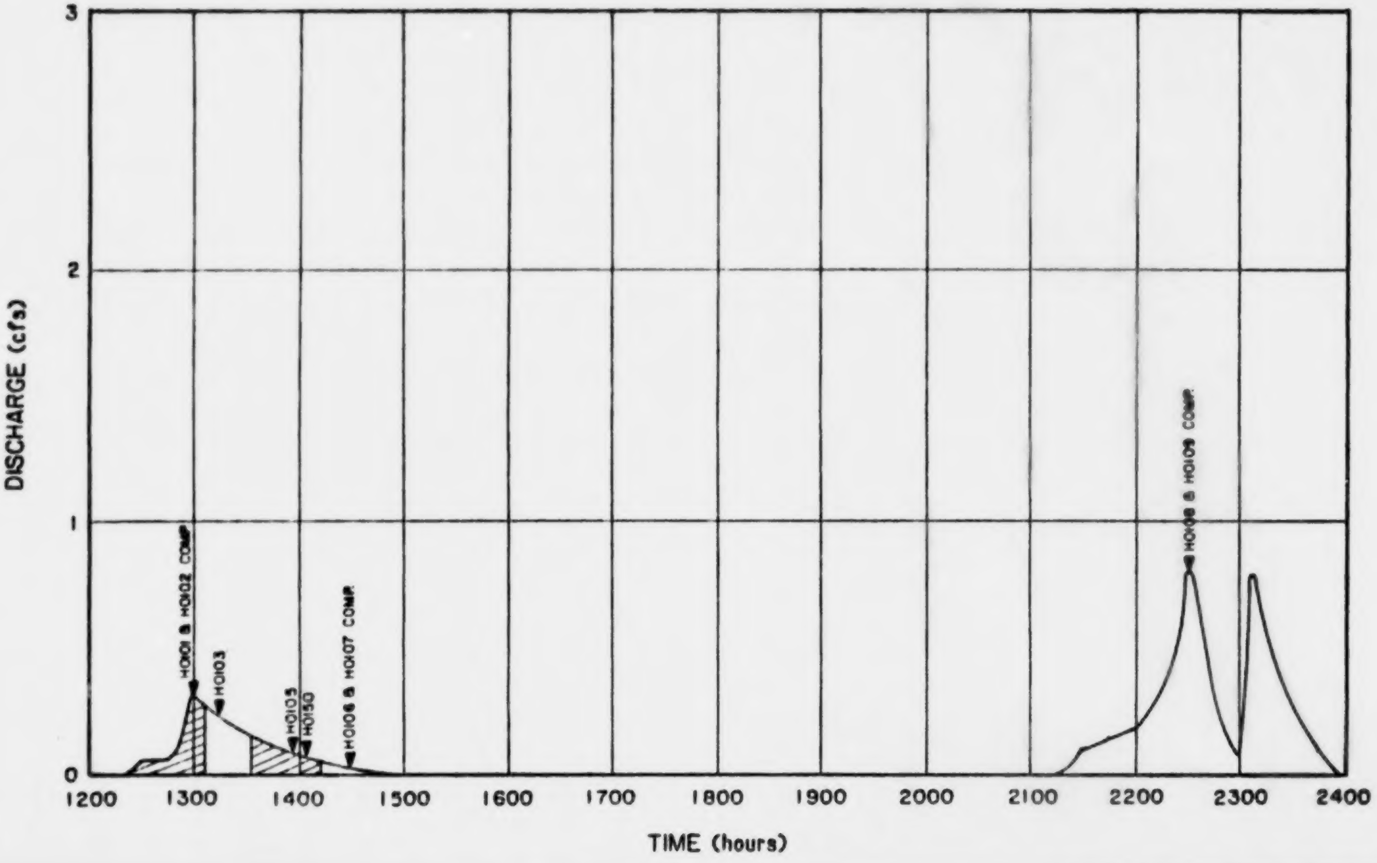
NOTES : NO FLOW BETWEEN 1440 AND 2120

HYDROGRAPH

HART LANE SITE

EVENT 01

2/4/81



DATE : 2/10/81
SITE : HART LANE
EVENT NO. : 02

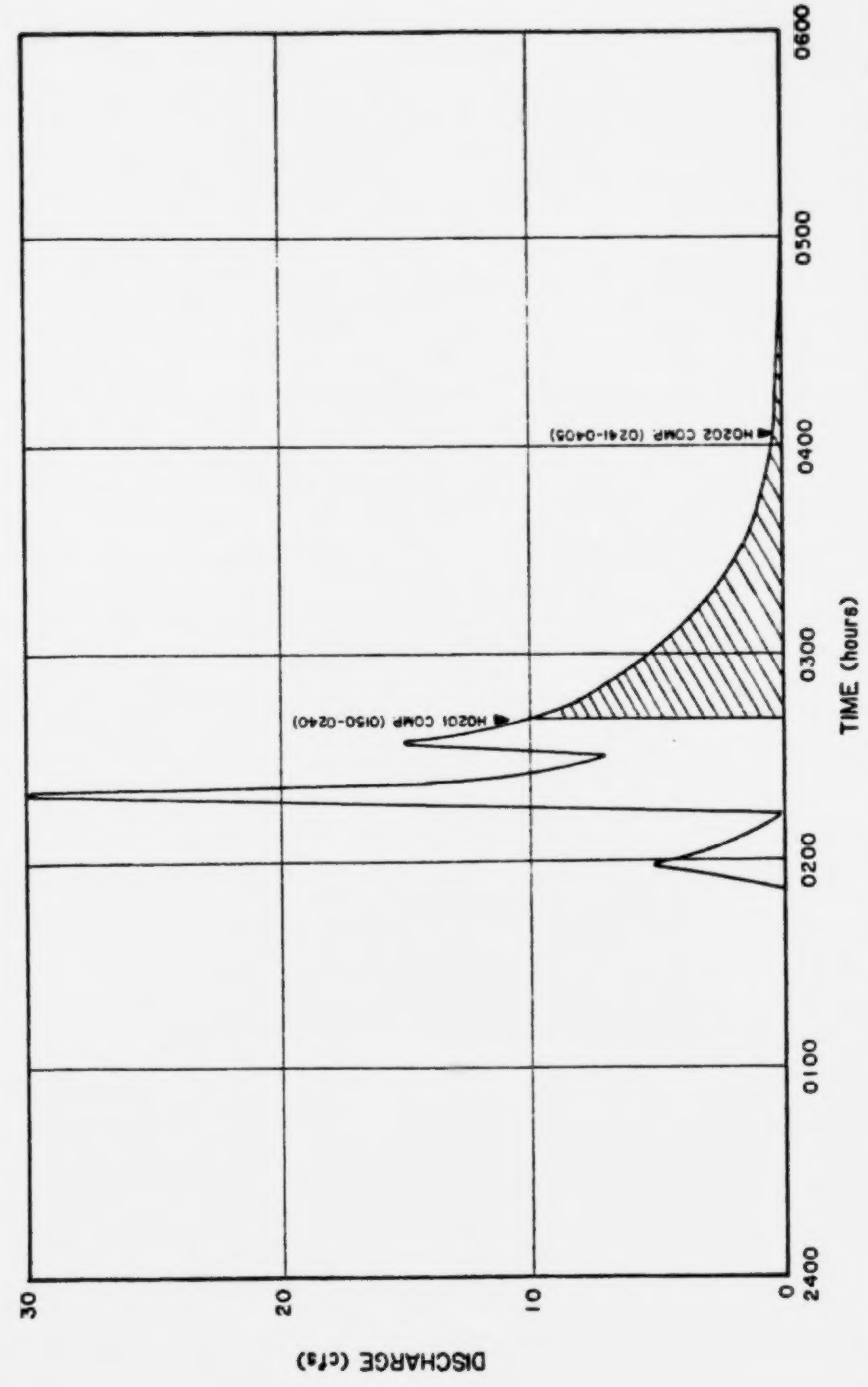
TABLE B-2

TIME	INST DIS (cfs)	INST POLL CONC (mg/l)					AVG MASS FLUX (lb/hr)					CUM MASS DISCHARGED (lbs)				
		COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS
0230	11.0	114.	35.8	2.00	0.13	143.	214.3	67.3	3.76	0.24	268.8	178.6	56.1	3.13	0.20	224.0
0245	7.0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
0300	5.0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
0315	3.5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
0330	1.5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
0345	0.8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
0405	0.4	171.	43.8	1.73	0.41	287.	80.3	20.6	0.81	0.19	134.7	359.2	102.4	4.96	0.63	527.2

NOTES : The two samples which were collected were composites.

FIGURE B-2

HYDROGRAPH
HART LANE SITE
EVENT 02
2/10/81



DATE : 3/07/81

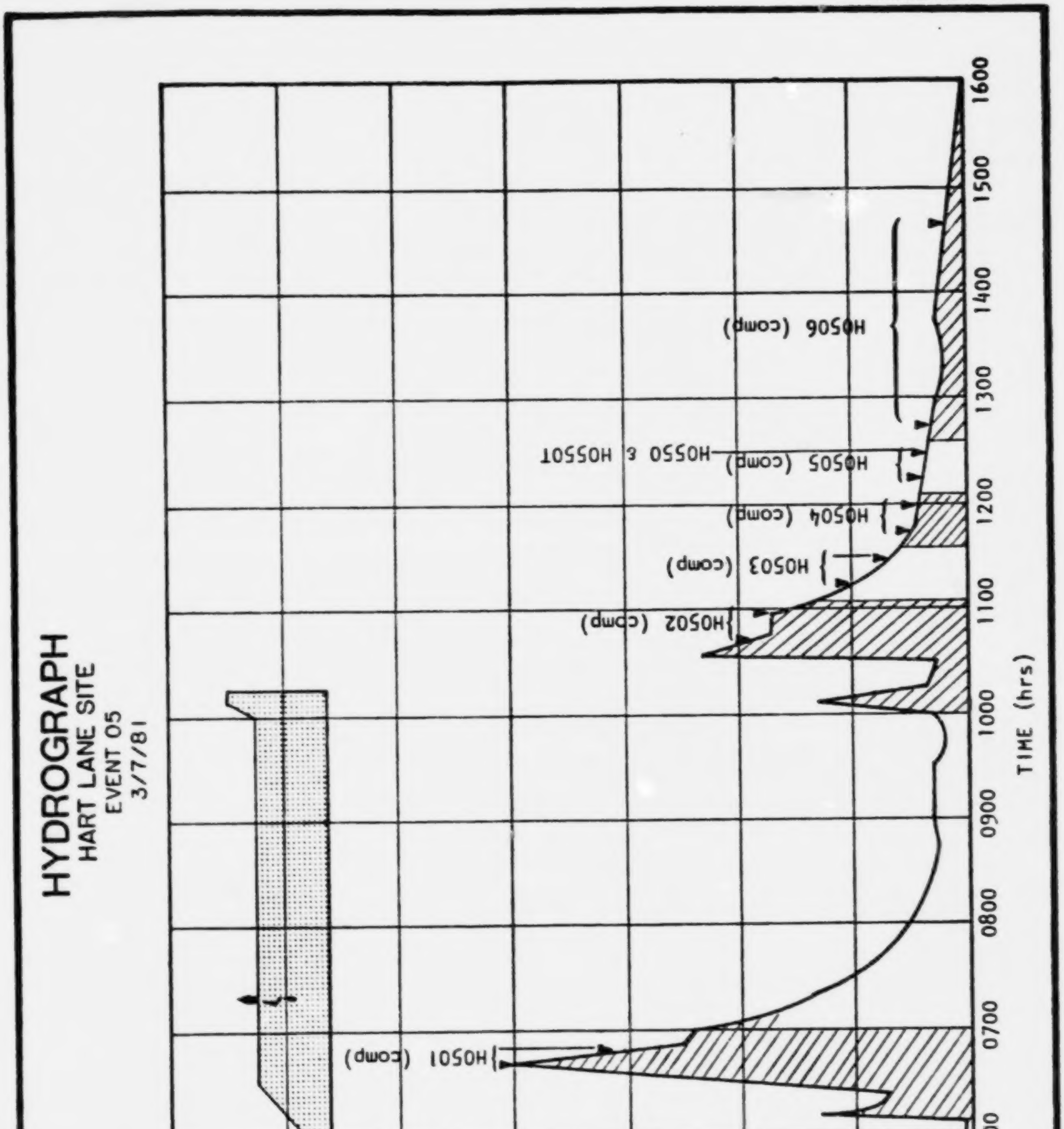
SITE : HART LANE

TABLE B-3

EVENT NO. : 05

TIME	INST DIS (cfs)	INST POLL CONC (mg/l)					AVG. MASS FLUX (lb/hr)					CUM MASS DISCHARGED (lb)				
		COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS
0648	7.0	38.	14.2	1.38	0.28	73.	24.8	9.8	0.93	0.19	50.1	31.0	12.3	1.16	0.24	62.6
0700	4.6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0730	2.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0800	1.0	(38)	(3.0)	(1.30)	(0.21)	(48)	18.3	1.4	0.63	0.10	23.1	49.3	13.7	1.79	0.34	85.7
0830	0.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0900	0.5	(38)	(3.0)	(1.30)	(0.21)	(48.)	5.5	0.4	0.19	0.03	6.9	54.8	14.1	1.98	0.37	92.6
0930	0.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1000	1.0	(38)	(3.0)	(1.30)	(0.21)	(48)	9.1	0.7	0.31	0.05	11.6	63.9	14.8	2.29	0.42	104.2
1100	3.0	38.	4.0	1.22	0.14	23.	17.7	1.9	0.57	0.07	10.7	81.6	16.7	2.86	0.49	114.9
1130	2.0	27.	6.3	1.08	0.11	17.	10.8	2.5	0.44	0.04	6.8	87.0	18.0	3.08	0.51	118.3
1200	1.0	15.	2.9	0.77	0.06	9.	3.1	0.6	0.16	0.02	0.7	88.6	18.3	3.16	0.52	118.6
1230	0.8	19	6.7	0.85	0.08	6.	3.4	1.2	0.14	~0	1.1	90.3	18.9	3.23	0.52	119.1
1300	0.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1330	0.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1400	0.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1430	0.4	19.	4.0	0.65	0.06	11.	1.6	0.3	0.05	0.01	0.9	95.6	20.0	3.41	0.54	122.2

NOTES : CONCENTRATIONS IN PARENTHESES
ARE ESTIMATES.


HYDROGRAPH
HART LANE SITE
EVENT 05
3/7/81
CUMULATIVE RAINFALL (in)
0.3
0.2
0.1
0
DISCHARGE (cfs)
14
12
10
8
6
4
2
0
TIME (hrs)
0400
0500
0600
0700
0800
0900
1000
1100
1200
1300
1400
1500
1600
H0501 (comp)
H0502 (comp)
H0503 (comp)
H0504 (comp)
H0505 (comp)
H0550 & H0550T
H0506 (comp)

DATE : 3/12/81

SITE : HART LANE

EVENT NO. : 06

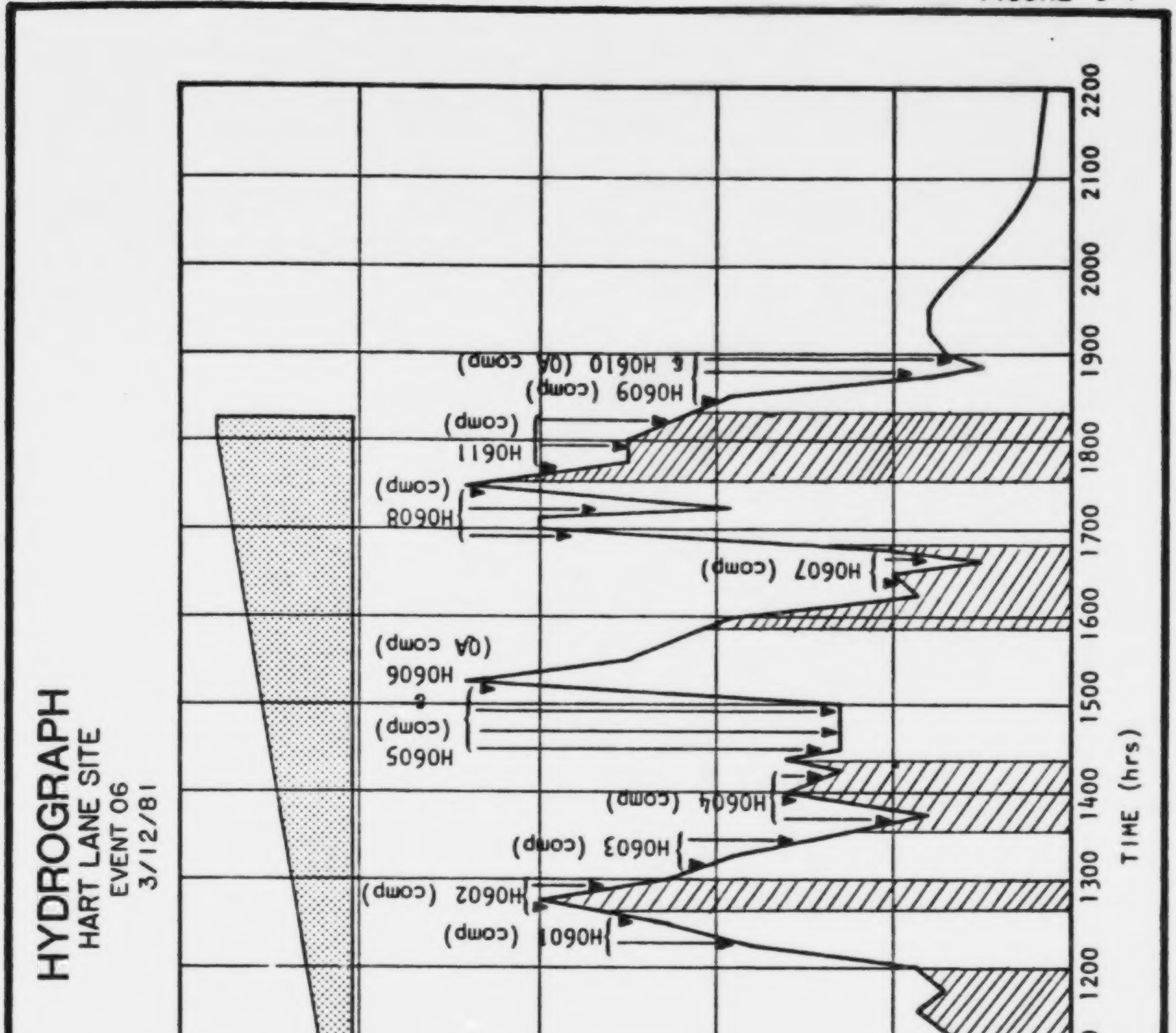
TABLE B-4

TIME	INST DIS (cfs)	INST POLL CONC (mg/l)					AVG. MASS FLUX (lb/hr)					CUM MASS DISCHARGED (lbs)				
		COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS
1200	0.8	(60.)	(15.0)	(1.10)	(0.17)	(85.)	5.67	1.42	0.10	0.02	8.0	32.6	8.15	0.60	0.09	46.2
1230	2.	72	15.6	1.07	0.17	70.	27.6	6.0	0.41	0.07	26.9	49.0	11.7	0.84	0.13	62.1
1300	3.	42.	15.9	0.92	0.17	26.	23.1	8.7	0.52	0.10	14.3	58.4	15.3	1.05	0.17	67.9
1330	2.	122.	15.1	0.97	0.15	30.	45.5	5.6	0.35	0.06	11.2	82.8	18.3	1.24	0.20	73.9
1400	1.	(95.)	(13.0)	(1.25)	0.15	54.	26.5	3.6	0.34	0.04	15.1	104.4	21.2	1.52	0.23	86.2
1500	2.	69.	11.4	1.60	0.15	3.	30.6	5.1	0.67	0.07	1.3	148.6	28.5	2.48	0.33	88.1
1640	1.	30.	10.5	0.53	0.07	9.	7.9	2.8	0.14	0.02	2.4	156.2	31.2	2.61	0.35	90.4
1730	3.	38.	14.0	0.89	0.13	13.	22.0	8.1	0.51	0.08	7.5	173.3	37.5	3.01	0.41	96.3
1830	3.	50.	14.1	0.61	0.09	10.	28.8	8.1	0.35	0.06	5.8	194.2	43.4	3.26	0.45	100.4
1900	1.	69.	16.2	1.01	0.11	20.	9.3	2.2	0.14	0.01	2.7	227.4	51.2	3.75	0.50	110.1

TIME	CUMULATIVE RAINFALL (inches)	CUMULATIVE DISCHARGE (ft^3)
200	0.08	8,400
230	0.09	14,500
300	0.10	16,000
1330	0.15	20,000
1400	0.18	24,000
1500	0.19	32.000
1640	0.21	40.000
1730	0.25	46.000
1830	0.28	50,000
1900	0.28	60,000

NOTES : CONCENTRATIONS IN PARENTHESES ARE ASSUMED.

FIGURE B-4


HYDROGRAPH
HART LANE SITE
EVENT 06
3/12/81
CUMULATIVE RAINFALL (in)
0.3
0.2
0.1
0
DISCHARGE (cfs)
5
4
3
2
1
0
TIME (hrs)
0600
0700
0800
0900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
H0601 (comp)
H0602 (comp)
H0603 (comp)
H0604 (comp)
H0605 (comp) & H0606 (QA comp)
H0607 (comp)
H0608 (comp)
H0611 (comp)
H0609 (comp)
& H0610 (QA comp)

DATE : 3/28 – 3/29 /81
SITE : HART LANE
EVENT NO. : 07

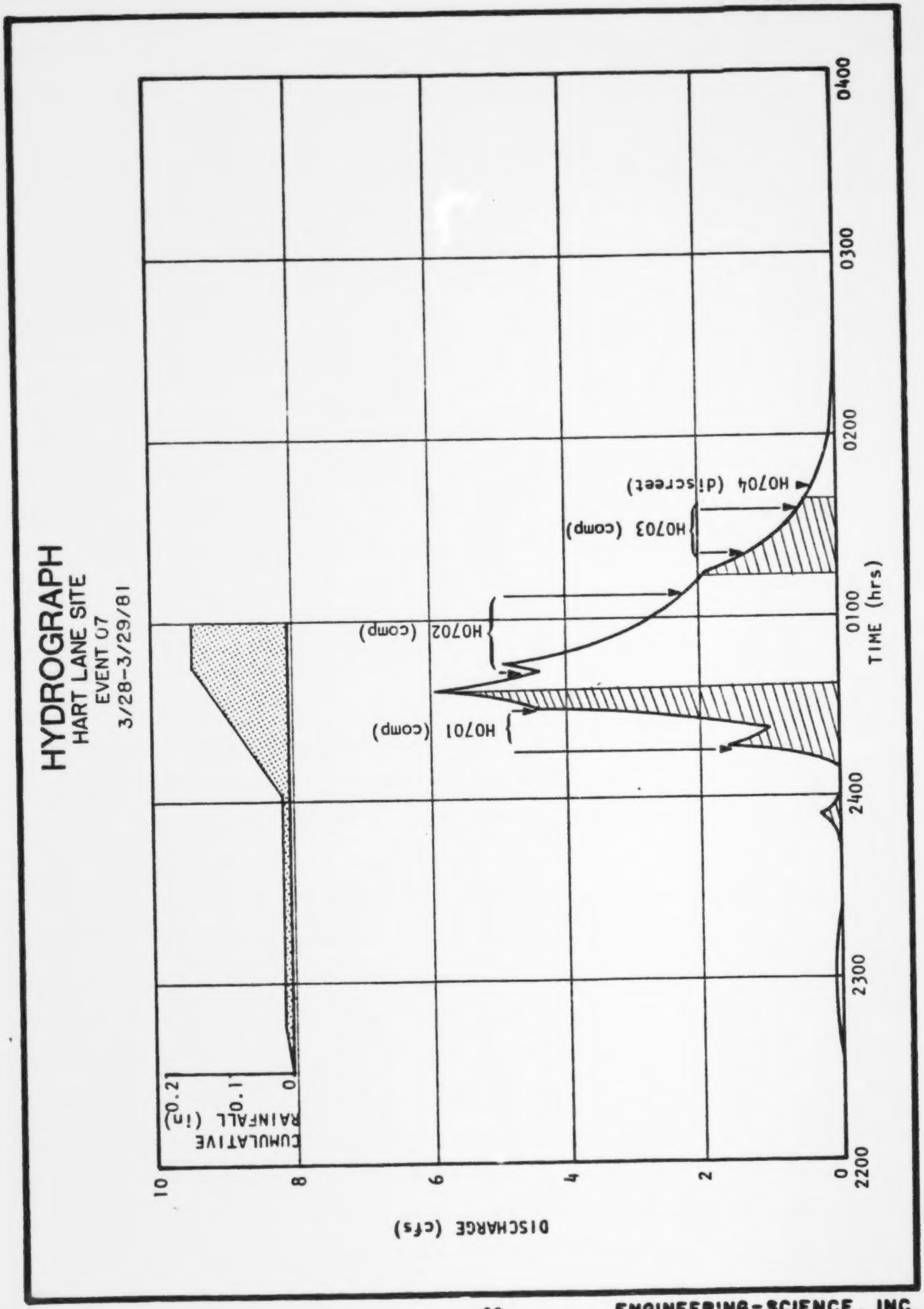
TABLE B-5

TIME	INST DIS (cfs)	INST POLL CONC (mg/l)					AVG MASS FLUX (lb/hr)					CUM MASS DISCHARGED (lbs)				
		COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS
0040c (3/29)	3.	135.	44.4	4.00	1.70	653.	49.4	16.3	1.46	0.62	236.9	28.8	9.5	0.85	0.36	138.2
0118c	4	75.	47.8	3.00	0.62	230.	57.4	36.6	2.29	0.47	175.9	65.1	32.7	2.30	0.66	249.6
0140c	1.	120.	41.7	2.50	0.45	47.	28.7	9.9	0.60	0.11	11.2	75.6	36.3	2.52	0.70	269.0
0150	0.3	83.	34.6	2.30	0.28	34.	2.3	0.9	0.07	0.01	0.9	77.3	37.0	2.57	0.71	269.7

TIME	CUMULATIVE RAINFALL (inches)	CUMULATIVE DISCHARGE (ft^3)
0040	0.14	3,800
0118	0.18	5,000
0140	0.18	13,000
0150	0.18	14,000

NOTES : ALL SAMPLES LABELED "C" ARE COMPOSITES

FIGURE B-5


HYDROGRAPH
HART LANE SITE
EVENT 07
3/28–3/29/81

ENGINEERING-SCIENCE, INC.

DATE : 4/17/81

SITE : HART LANE

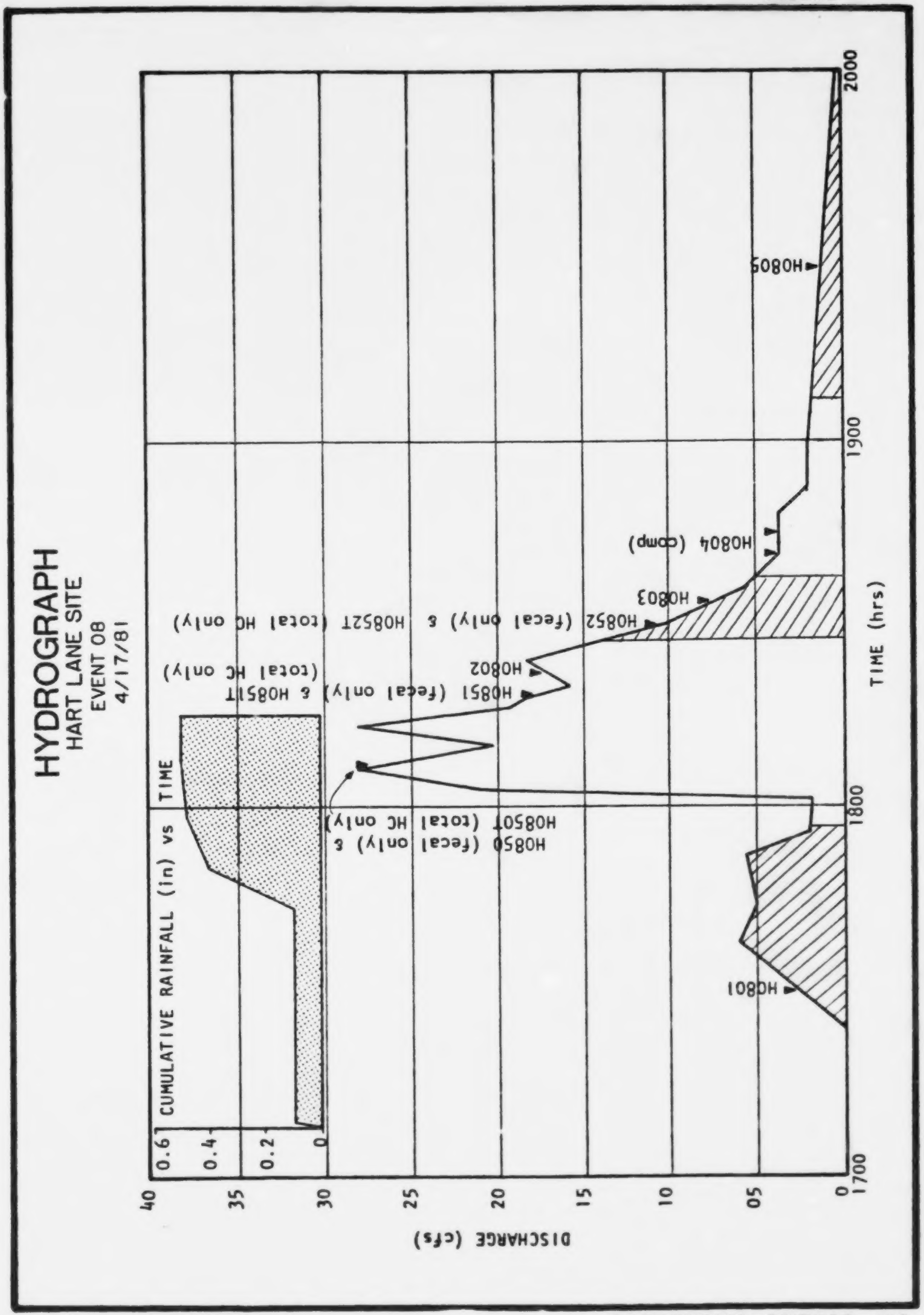
TABLE B-6

EVENT NO. : 08

TIME	INST DIS (cfs)	INST POLL CONC (mg/l)					AVG. MASS FLUX (lb/hr)					CUM MASS DISCHARGED (lbs)				
		COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS
1730		754.	270.	5.90	3.40	1428.	663.	–	5.18	2.98	1255.	397.5	142.4	3.11	1.79	752.9
1820		114.	56.9	2.31	0.58	168	472.	–	9.56	2.40	695.	625.6	256.2	7.73	2.95	1088.9
1835		114.	–	2.18	0.52	88	253.	–	4.80	1.13	195	663.5	–	8.45	3.12	1118.2
1845		103.	–	2.42	0.51	44.	58.	–	1.36	0.29	24.7	689.5	–	9.06	3.25	1129.3
1930		76.	–	1.31	0.41	36	22.	–	0.38	0.12	10.4	709.5	–	9.41	3.36	1138.8

TIME	CUMULATIVE RAINFALL (inches)	CUMULATIVE DISCHARGE (ft^3)
1730	0.10	8,500
1820	0.52	26,000
1835	0.52	45,000
1845	0.52	50,000
1930	0.52	50,000

NOTES :



HYDROGRAPH
HART LANE SITE
EVENT 08
4/17/81

DATE : 5/16/81

SITE : HART LANE

EVENT NO. : 14

TABLE B-7

TIME	INST DIS (cfs)	INST POLL CONC (mg/l)					AVG MASS FLUX (lb/hr)					CUM MASS DISCHARGED (lbs)				
		COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS
0200	4.8	84.	—	2.41	0.31	134	44.4		1.27	0.16	70.8	50.0	—	1.43	0.18	79.7
0215	15.6	110.	—	2.80	0.51	202.	376.8	—	9.60	1.76	619.9	144.2	—	3.83	0.62	252.7
0230	10.0	49.	—	2.17	0.34	92.	129.4	—	5.72	0.88	243.0	176.6	—	5.26	0.84	313.5
0245	10.0	76.	—	2.55	0.37	538.	209.6	—	7.04	1.04	1483.6	229.0	—	7.02	1.10	684.4
0500	1.9	(38.)	—	(2.80)	(0.20)	(30.)	19.6	—	0.93	1.03	15.5	307.6	—	10.74	1.51	746.4

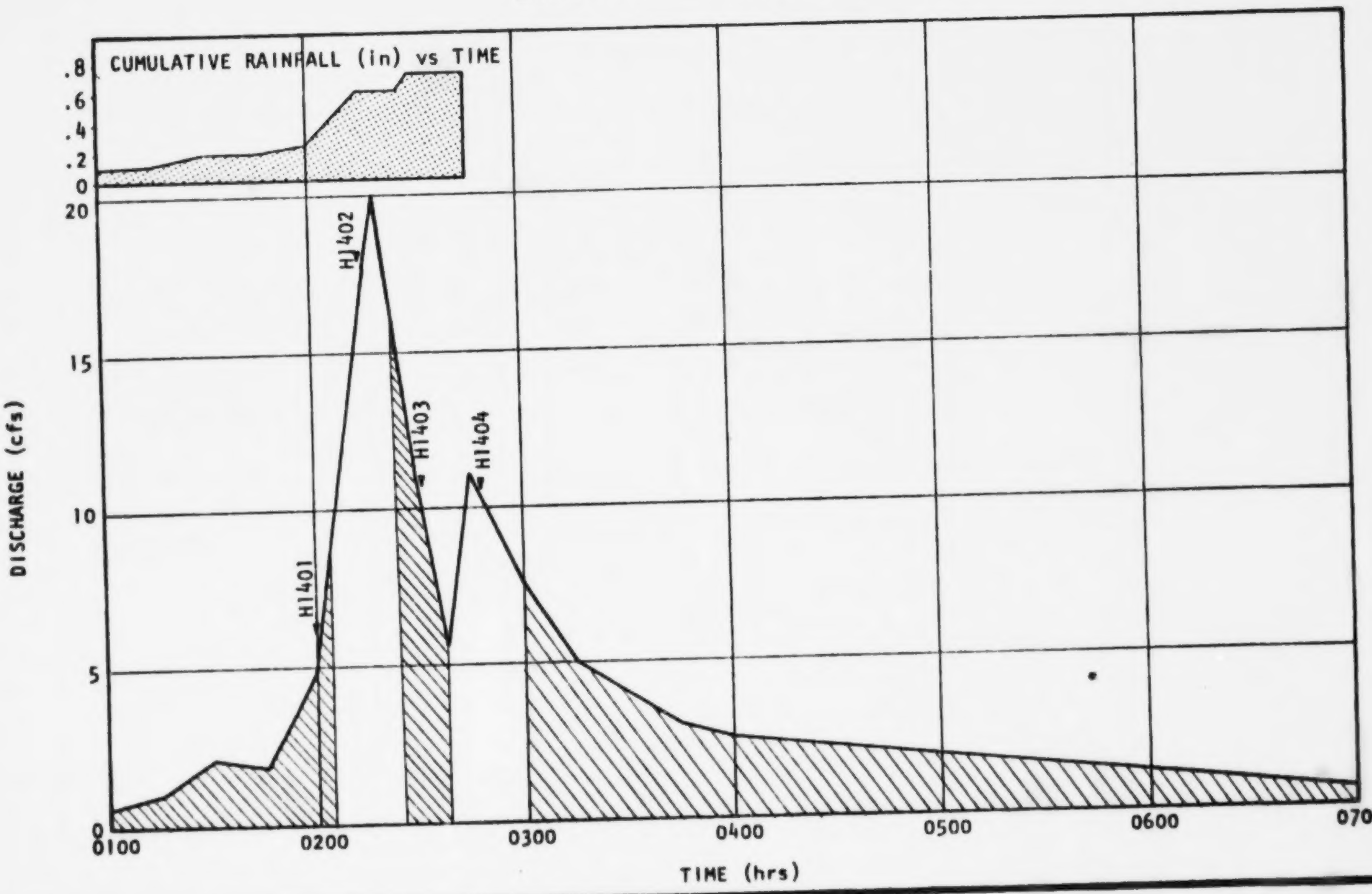
TIME	CUMULATIVE RAINFALL (inches)	CUMULATIVE DISCHARGE (ft³)
0200	0.20	9,000
0215	0.50	20,000
0230	0.60	35,000
0245	0.70	45,000
0500	0.70	80,000

NOTES : ALL VALUES IN PARENTHESES ARE ESTIMATES

FIGURE B-7

HART LANE

EVENT 14 5/16/81



DATE : 5/23 – 5/24/81

SITE : HART LANE

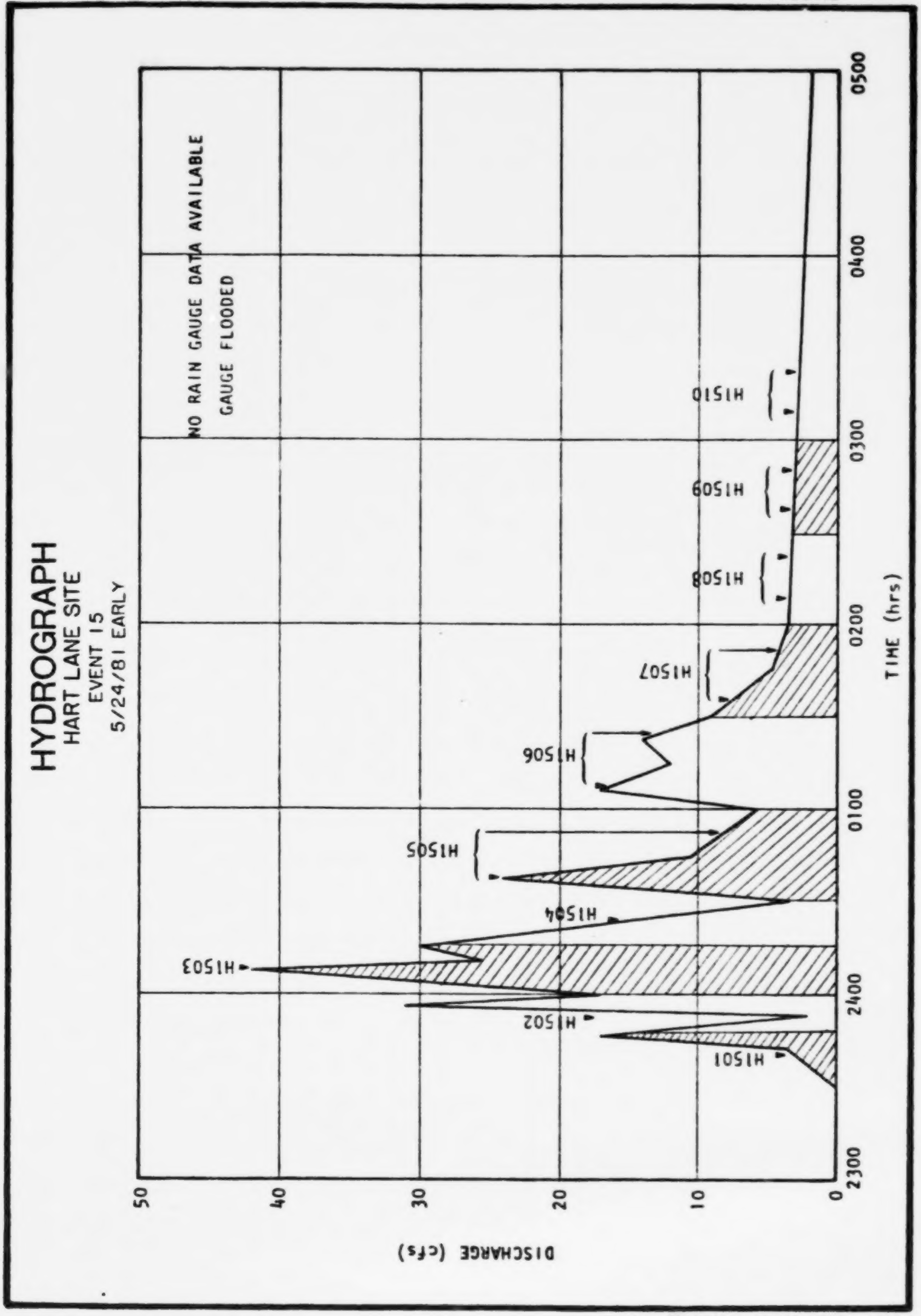
TABLE B-8

EVENT NO. : 15

TIME	**INST DIS (cfs)**	**INST POLL CONC** (mg/l)					AVG **MASS FLUX (lb/hr)**					**CUM MASS DISCHARGED** (lbs)				
		COD	**TOC**	**NH_3-N**	**TOT P**	**TSS**	**COD**	**TOC**	**NH_3-N**	**TOT P**	**TSS**	**COD**	**TOC**	**NH_3-N**	**TOT P**	**TSS**
2340 (5/23)	3	88.	24 1	1.63	0.34	470.	80.	21.7	1.47	0.30	420.	24	6.5	0 44	0.09	126.
2355 (5/23)	16.	38.	12 3	1.45	0.26	248.	128.	41.6	4 88	0.88	836.	56	16.9	1.66	0 31	335.
0010 (5/24)	42	76	31.4	2 50	0 55	570.	492	202.8	16.12	3 56	3680	179.	67 6	5.69	1.20	1255.
0025	12	99.	23.2	1.33	0 50	508.	240	56.4	3 24	1.20	1240.	239	81 7	6 50	1.50	1565.
0055	15.	133	8 5	1.01	0 57	220.	310	19 8	2 36	1.32	512	394.	91.6	7.68	2.16	1821.
0125	13	152	12.8	0 09	0.51	208.	420	35.4	0.24	1.40	574.	604.	109 3	7.80	2 86	2108.
0155	5	49	14.0	1.53	0.45	86.	48.	13 6	1 48	0.44	84.	628.	116.1	8.54	3 08	2150
0225	3	38.	13 1	1.79	0 37	45.	26	9 0	1.22	0.26	30.	641.	120 6	9.15	3.21	2165
0255	3	19.	13 4	1 20	0 33	28	12	8.2	0.74	0.20	18.	647	124.7	9.52	3.31	2174
0325	2	19.	11 4	1 07	0.26	17.	9 1	5.5	0.51	0.13	8.2	667.	136 8	10.65	3.59	2192.

TIME	**CUMULATIVE RAINFALL (inches)**	**CUMULATIVE DISCHARGE (ft^3)**
2340		4,200
2356		19,000
0010		42,000
0025		70,000
0055		78,000
0125		98,000
0155		110,000
0255		135,000
0325		145,000

NOTES :



HYDROGRAPH
HART LANE SITE
EVENT 15
5/24/81 EARLY

DATE : 6/1/81

SITE : HART LANE

EVENT NO. : 18

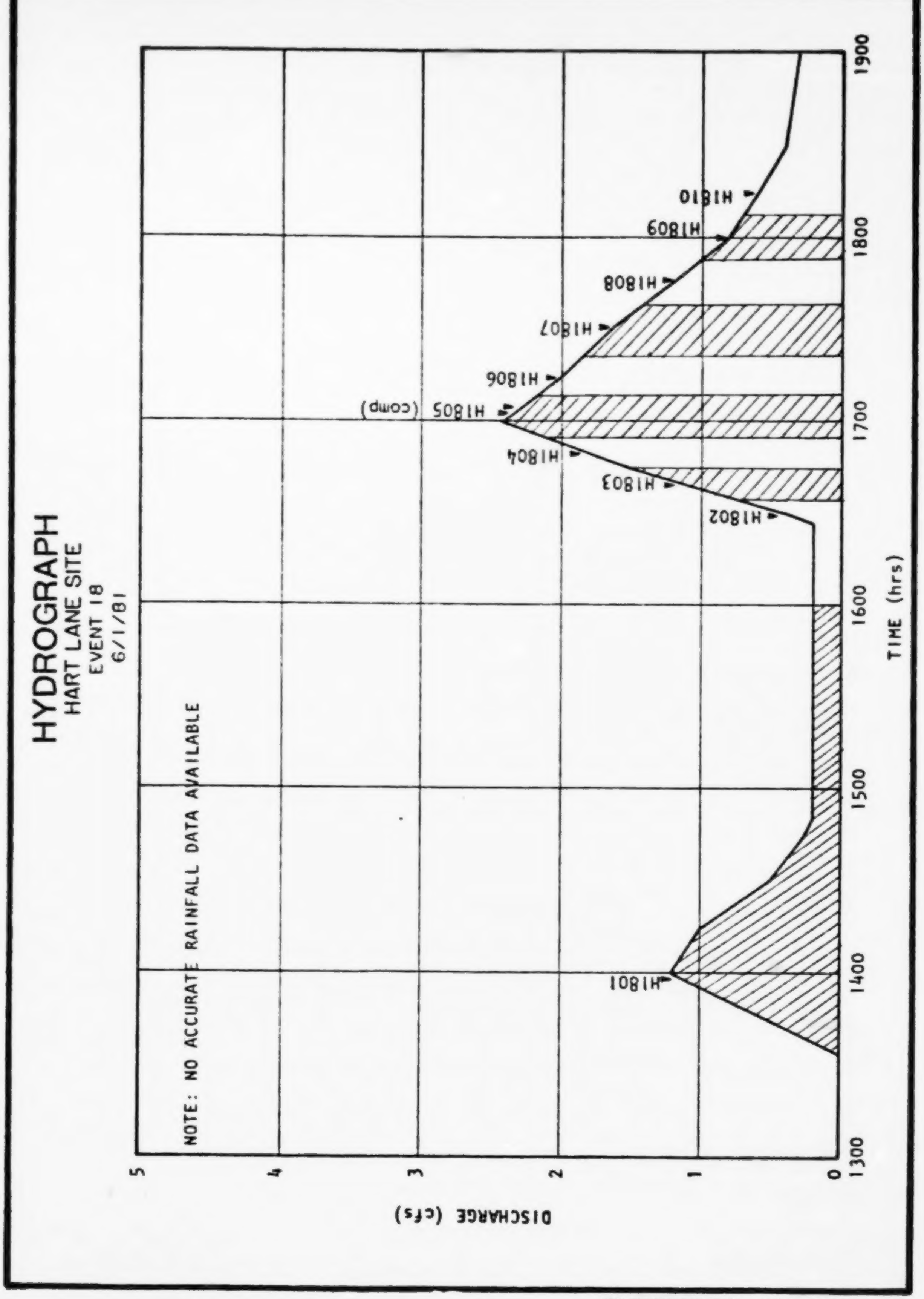
TABLE B-9

TIME	INST DIS (cfs)	INST POLL CONC (mg/l)					AVG MASS FLUX (lb/hr)					CUM MASS DISCHARGED (lbs)				
		COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS
1355	1.1	38.	9.0	1.63	0.18	200.	3.0	0.73	0.13	0.01	16.1	7.1	1.7	0.31	0.03	37.5
1632	0.5	46.	9.7	0.61	0.17	44.	4.7	0.98	0.06	0.02	4.5	10.0	2.3	0.35	0.05	40.3
1642	1.3	42.	9.6	0.60	0.35	33.	11.1	2.54	0.16	0.09	8.7	11.9	2.7	0.37	0.06	41.7
1652	2.0	107.	22.1	1.89	0.29	378.	43.3	8.95	0.77	0.12	153.0	20.5	4.5	0.53	0.08	72.3
1706	2.3	30	14.2	1.13	0.22	27	14.4	6.84	0.55	0.10	13.0	23.2	5.8	0.63	0.10	74.7
1714	2.1	30.	5.8	0.41	0.06	15.	13.8	2.67	0.19	0.03	6.9	25.9	6.3	0.67	0.11	76.1
1730	1.6	4	6.7	0.43	0.11	22.	1.54	2.58	0.17	0.04	8.5	26.3	7.0	0.71	0.12	78.3
1745	1.2	38	5.3	0.42	0.09	17.	10.1	1.40	0.11	0.02	4.5	28.8	7.3	0.74	0.13	79.4
1800	0.8	30	4.3	0.73	0.09	16	5.3	0.76	0.13	0.02	2.8	30.2	7.5	0.77	0.13	80.1
1815	0.6	38	3.3	0.90	0.12	16	4.5	0.39	0.11	0.01	1.9	34.1	7.9	0.86	0.14	81.7

TIME	CUMULATIVE RAINFALL (inches)	CUMULATIVE DISCHARGE (ft^3)
1355	-	3,200
1632	-	4,000
1642	-	4,300
1652	-	6,000
1706	-	6,200
1714	-	6,500
1730	-	10,000
1745	-	12,000
1800	-	13,000
1815	-	13.500

NOTES :

FIGURE B-9


HYDROGRAPH
HART LANE SITE
EVENT 18
6/1/81
NOTE: NO ACCURATE RAINFALL DATA AVAILABLE
DISCHARGE (cfs)
0
1
2
3
4
5
TIME (hrs)
1300
1400
1500
1600
1700
1800
1900
H1801
H1802
H1803
H1804
H1805 (comp)
H1806
H1807
H1808
H1809
H1810

DATE : 6/2/81
SITE : HART LANE
EVENT NO. : 19

TABLE B-10

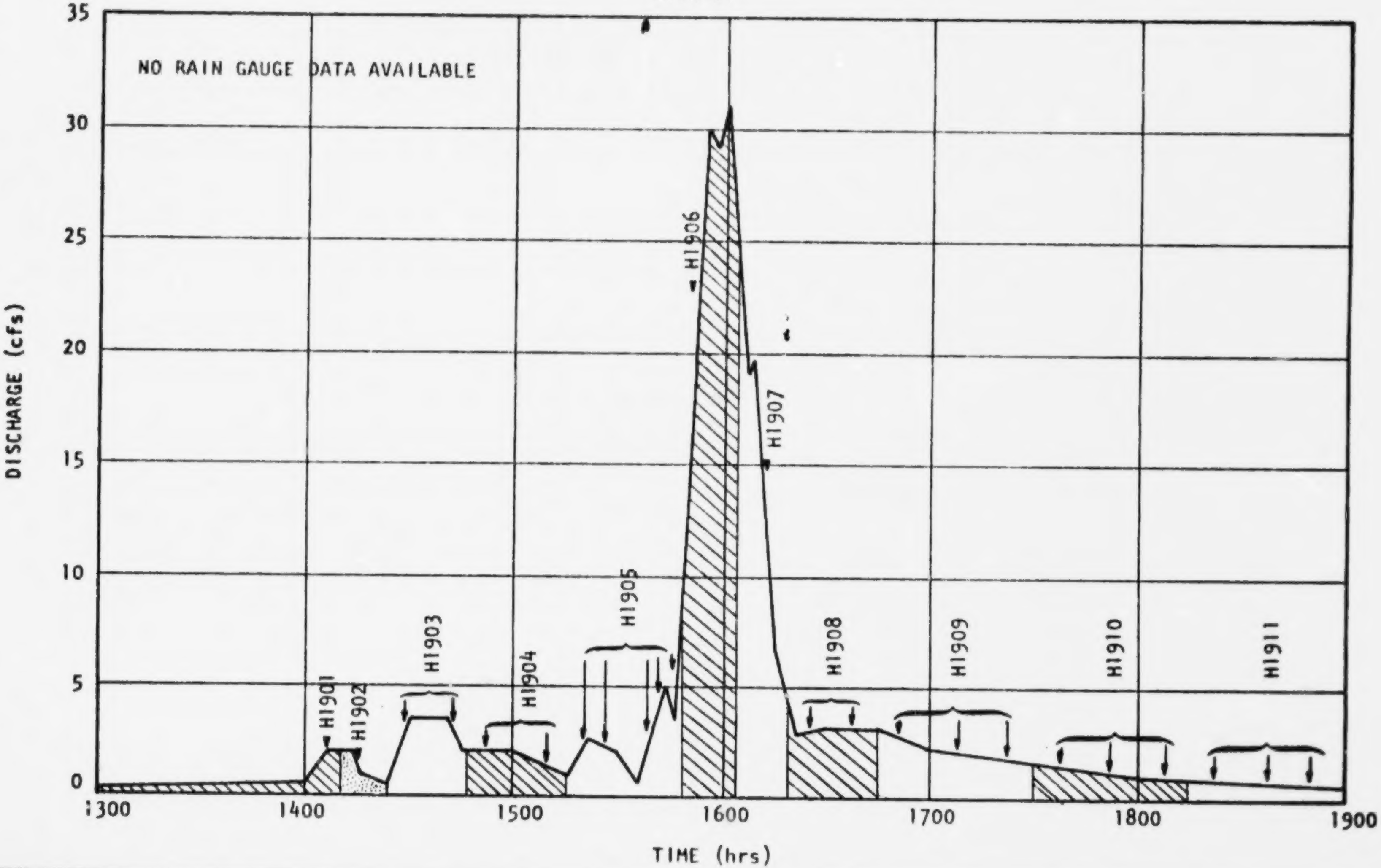
TIME	INST DIS (cfs)	INST POLL CONC (mg/l)					AVG MASS FLUX (lb/hr)					CUM MASS DISCHARGED (lbs)				
		COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS
1408	1.8	95.	27.9	1.67	0.29	340	6.5	1.9	0.12	0.02	23.1	8.4	2.5	0.15	0.03	30.
1415	1.2	72.	15.1	1.56	0.20	164	17.8	3.9	0.39	0.05	39.5	11.1	3.1	0.21	0.04	36
1440	3.0	42	17.7	0.97	0.26	288	24.8	10.5	0.58	0.15	170	21.0	7.3	0.44	0.10	104
1510	1.0	42	15.4	0.73	2.30	29	13.6	5.0	0.24	0.74	9.4	27.8	9.8	0.56	0.47	109.
1550	6.0	53.	18.0	1.77	0.21	148	32.3	10.9	1.07	0.13	90.	45.0	15.6	1.13	0.54	157.
1555	23.0	160.	17.9	1.93	0.26	289	922.5	103.3	11.13	1.50	1666.	298.7	44.0	4.19	0.95	615.
1610	10.0	84	16.0	1.40	0.34	152	272.5	52.0	4.55	1.11	495.	353.2	54.4	5.10	1.17	714.
1640	3.4	95.	12.6	2.11	0.26	58.	74.7	10.0	1.67	0.20	46.7	386.8	58.9	5.85	1.26	735.
1725	1.6	11.	10.9	1.06	0.11	28	5.5	5.3	0.52	0.05	13.7	390.9	62.9	6.24	1.30	745.
1810	0.8	8.	6.6	0.73	0.13	6	1.7	1.5	0.16	0.03	1.3	392.2	64.0	6.36	1.32	746.
1855	0.6	15.	6.7	1.23	0.06	8	1.9	0.8	0.15	0.01	1.0	394.1	64.8	6.51	1.33	747

TIME	CUMULATIVE RAINFALL (inches)	CUMULATIVE DISCHARGE (ft^3)
1408	-	1,400
1415	-	2,000
1440	-	6,000
1510	-	8,000
1555	-	10,000
1610	-	11,000
1640	-	58,000
1725	-	64,000
1810	-	65.000
1855	-	65,000

NOTES :

FIGURE B-10

HYDROGRAPH
HART LANE SITE
EVENT 19
6/2/81



DATE : 6/03/81

SITE : HART LANE

TABLE B-11

EVENT NO. : 20

TIME	INST DIS (cfs)	INST POLL CONC (mg/l)					AVG MASS FLUX (lb/hr)					CUM MASS DISCHARGED (lbs)				
		COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS
1351	5.1	80.	9.2	0.97	0.15	60.	96.0	11.0	1.17	0.18	72	96.	11.0	1.17	0.18	72.
1438	3.1	19.	10.4	1.11	0.30	25.	16.3	8.9	0.95	0.25	21.3	108	17.7	1.88	0.37	88
1523	1.8	27.	8.8	0.88	0.14	13.	12.9	4.3	0.43	0.07	6.3	118	20.9	2.20	0.42	93
1608	1.2	38.	6.5	0.51	0.09	6.	12.0	2.0	0.16	0.03	1.9	127.	22.4	2.32	0.44	94.
1653	0.9	34	7.9	0.61	0.07	3.	7.9	1.9	0.15	0.02	0.7	133.	23.8	2.43	0.45	95.
1708	0.7	19.	9.5	0.56	0.09	4.	2.0	0.1	0.06	0.01	0.4	137.	24.0	2.55	0.47	96.

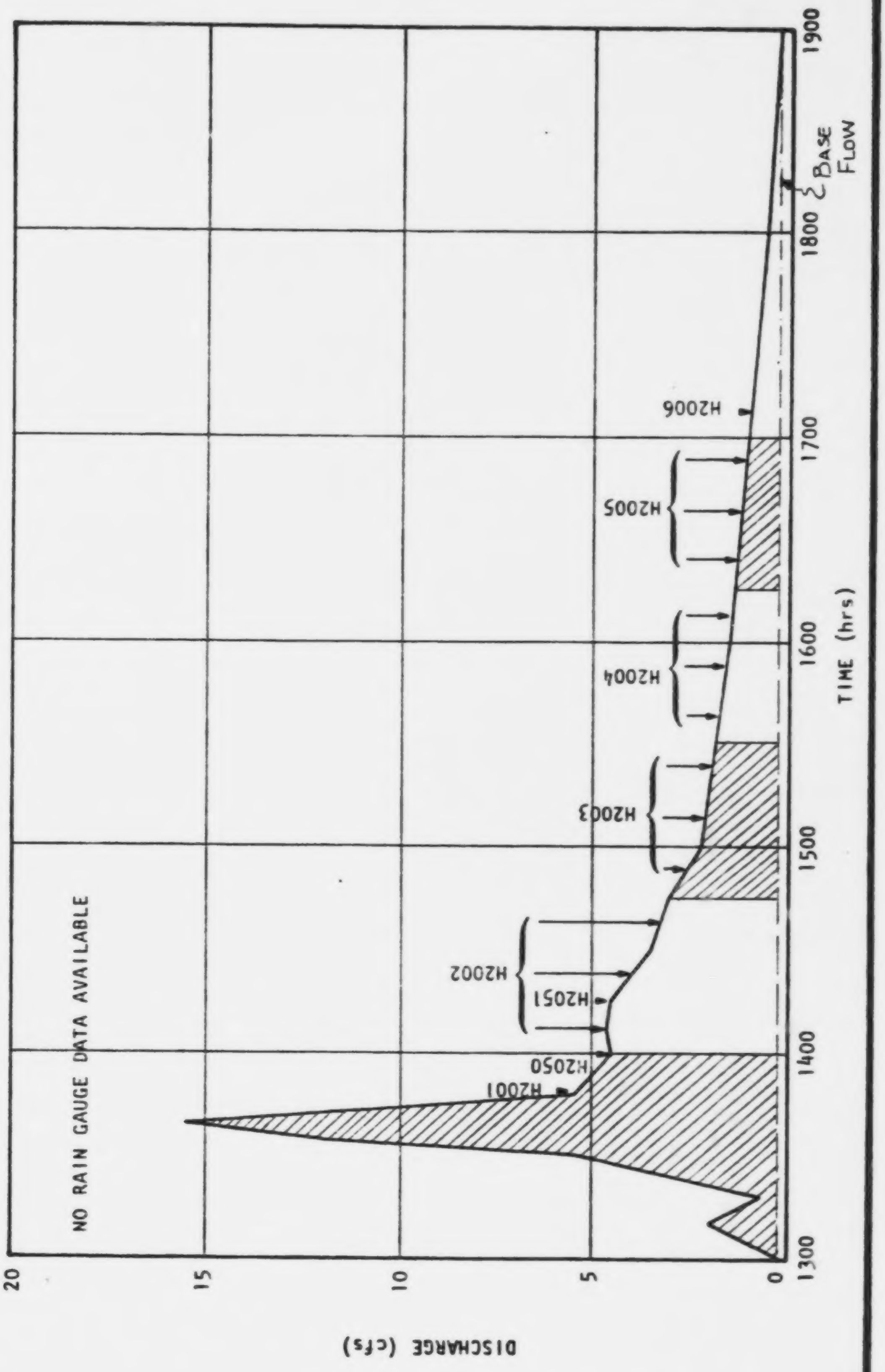
TIME	CUMULATIVE RAINFALL (inches)	CUMULATIVE DISCHARGE (ft^3)
1351	-	19,000
1438	-	28,000
1523	-	30,000
1608	-	40,000
1653	-	44,000
1708	-	45,000

NOTES : BASE FLOW ≅ 0.2 cfs,
VALUES ABOVE FOR DISCHARGE ARE THE ACTUAL MEASURED VALUES. TO OBTAIN STORM-GENERATED FLOWS SIMPLY SUBTRACT 0.2 cfs FROM THE ABOVE VALUES. MASSES WERE CALCULATED USING THE MEASURED VALUE FOR DISCHARGE.

FIGURE B-11

HART LANE

EVENT 20 6/3/81



DATE : 8/29/81

SITE : HART LANE

TABLE B-12

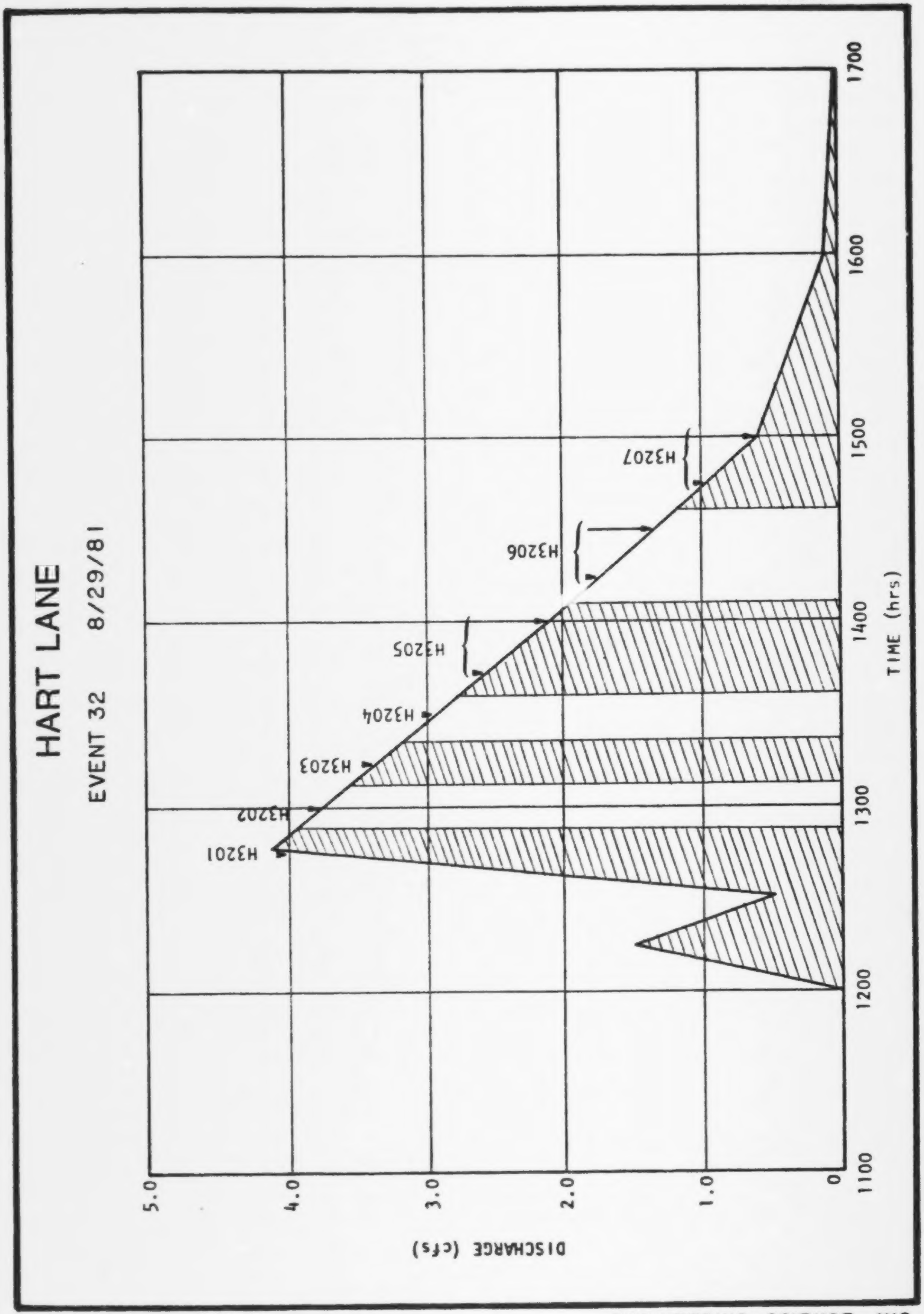
EVENT NO. : 32

TIME	INST DIS (cfs)	INST POLL CONC (mg/l)					AVG MASS FLUX (lb/hr)					CUM MASS DISCHARGED (lbs)				
		COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS
1245	3.8	–	18.4	1.49	0.18	87.	–	6.1	0.49	0.06	28.6	–	5.3	0.43	0.05	25.
1300	4.0	–	19.6	1.52	0.18	73.	–	17.2	1.36	0.16	64	–	9.7	0.77	0.09	41
1315	3.6	–	12.7	1.59	0.18	35.	–	10.8	1.36	0.16	30	–	12.4	1.11	0.13	49.
1330	3.2	–	13.3	1.75	0.16	39.	–	10.0	1.32	0.12	28.8	–	14.9	1.44	0.16	56.
1400	2.1	–	14.6	1.53	0.19	33.	–	7.8	0.82	0.10	17.6	–	18.8	1.85	0.21	65.
1430	1.2	–	12.8	1.18	0.13	5.	–	4.2	0.38	0.04	1.6	–	20.9	2.04	0.23	66.
1500	0.6	–	16.4	1.95	0.19	7.	–	0.8	0.10	0.01	0.3	–	22.8	2.27	0.25	67.

TIME	CUMULATIVE RAINFALL (inches)	CUMULATIVE DISCHARGE (ft^3)
1245	-	4,800
1300	-	8,000
1315	-	14,000
1330	-	16,000
1400	-	19,000
1430	-	22,000
1500	-	24,000

NOTES : ALL NH_3-N VALUES ABOVE ARE ACTUALLY TOTAL N VALUES

FIGURE B-12


HART LANE

EVENT 32 8/29/81

DATE : 8/30/81

SITE : HART LANE

EVENT NO. : 32.5

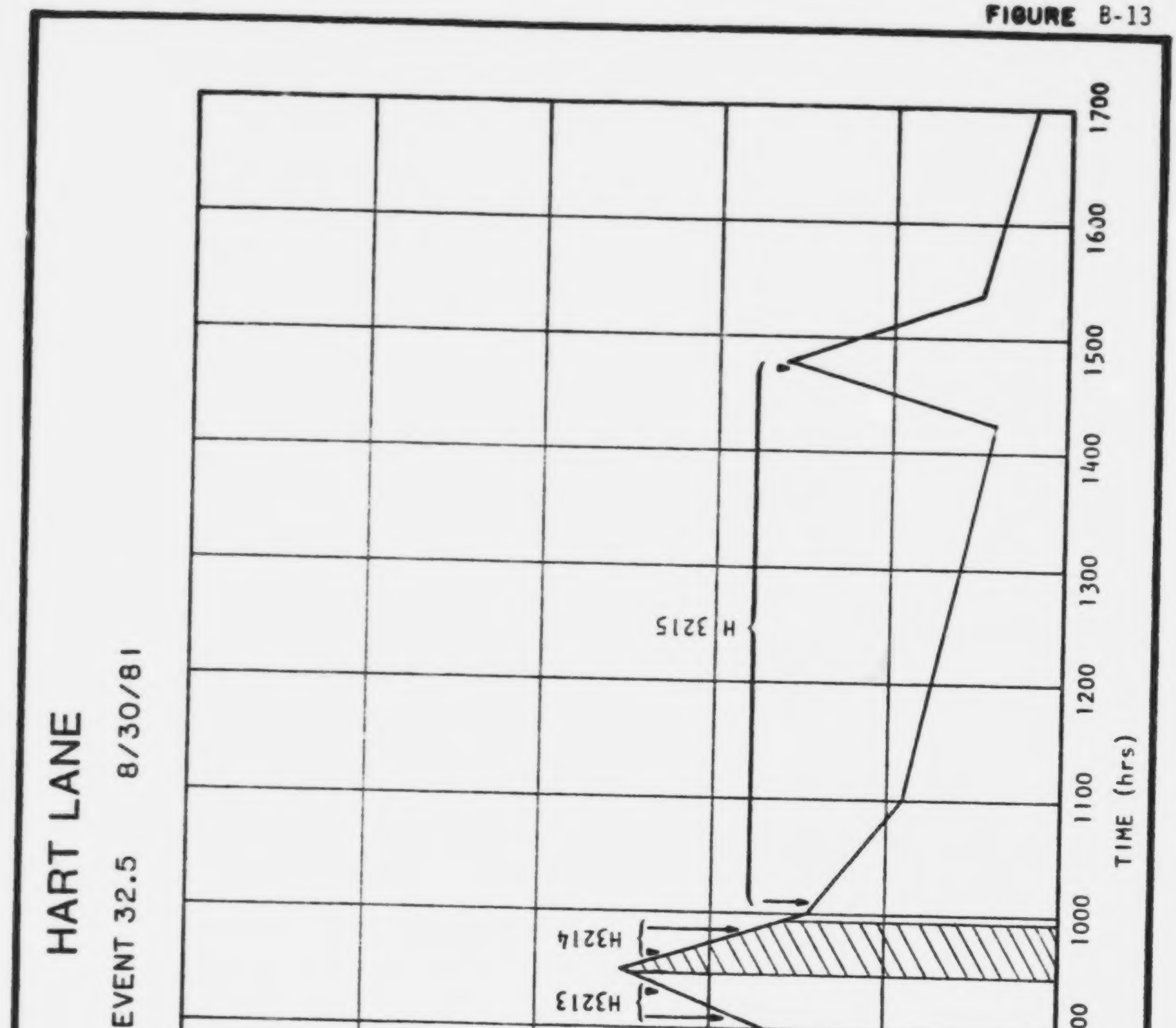
TABLE B-13

TIME	INST DIS (cfs)	INST POLL CONC (mg/l)					AVG MASS FLUX (lb/hr)					CUM MASS DISCHARGED (lbs)				
		COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS
0552	1.1	—	11.0	1.37	0.09	4	—	1.5	0.19	0.02	0.6	—	1.9	0.24	0.02	0.7
0608	1.6	—	9.2	1.33	0.11	5	—	3.2	0.48	0.04	2.0	—	2.7	0.36	0.03	1.2
0638	1.3	—	9.2	1.63	0.09	7	—	3.0	0.54	0.04	2.2	—	4.2	0.63	0.05	2.3
0708	0.9	—	8.7	1.33	0.06	1	—	1.5	0.23	0.01	0.2	—	5.9	0.89	0.06	2.5
0838	2.5	—	6.7	1.22	0.05	8	—	2.4	0.44	0.02	2.9	—	8.3	1.33	0.08	5.4
0923	2.3	—	8.2	1.81	0.11	12	—	3.6	0.82	0.05	5.4	—	10.6	1.85	0.11	8.8
0953	1.9	—	6.0	1.21	0.26	11	—	2.8	0.56	0.12	5.2	—	12.0	2.13	0.17	11.4
1445	1.5	—	9.7	1.29	0.07	15	—	1.5	0.20	0.01	2.3	—	22.0	3.46	0.24	26.8

TIME	CUMULATIVE RAINFALL (inches)	CUMULATIVE DISCHARGE (ft^3)
0552	-	2,900
0608	-	4,000
0638	-	6,000
0708	-	9,000
0838	-	16,000
0923	-	21,000
0953	-	25,000
1445	-	25,000

NOTES : ALL VALUES LISTED AS NH_3-N ARE ACTUALLY TOTAL N.

FIGURE B-13


HART LANE
EVENT 32.5 8/30/81
DISCHARGE (cfs)
5.0
4.0
3.0
2.0
1.0
0
TIME (hrs)
0500
0600
0700
0800
0900
1000
1100
1200
1300
1400
1500
1600
1700
H3208
H3209
H3210
H3211
H3212
H3213
H3214
H 3215

DATE : 9/14/81
SITE : HART LANE
EVENT NO. : 34

TABLE B-14

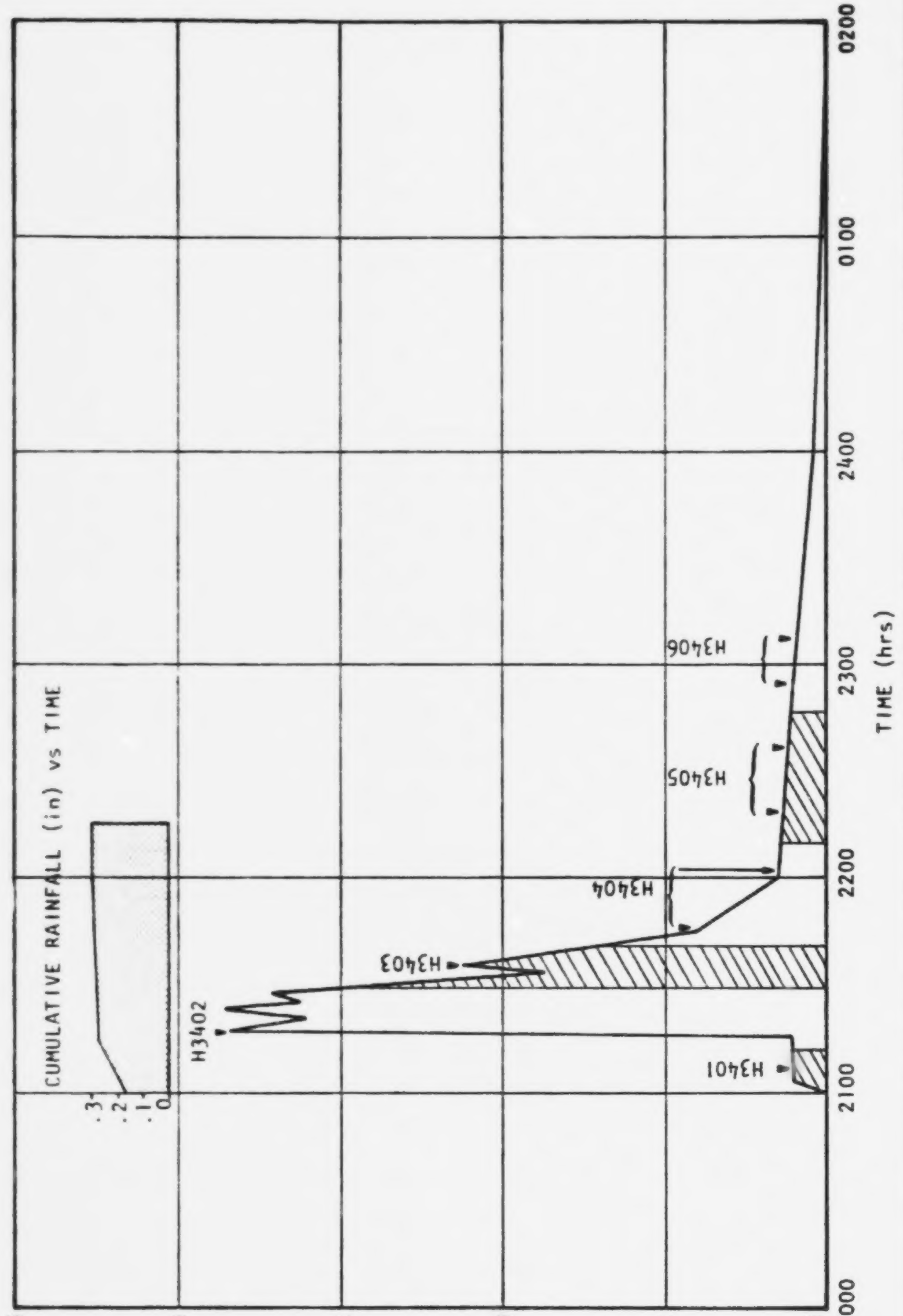
TIME	INST DIS (cfs)	INST POLL CONC (mg/l)					AVG MASS FLUX (lb/hr)					CUM MASS DISCHARGED (lbs)				
		COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS
2108	0.8	—	37.7	9.89	0.51	288	—	6.0	1.60	0.08	47	—	1.5	0.40	0.02	11.7
2117	18	—	35.5	11.50	0.56	518	—	126.0	40.70	1.96	1836	—	24.6	7.87	0.38	348.3
2138	12	—	22.1	11.10	0.32	170	—	62.4	31.20	0.92	479	—	40.2	15.68	0.61	468.0
2203	1.5	—	23.4	10.00	0.21	29	—	14.0	5.96	0.12	17.2	—	47.2	18.65	0.67	476.6
2233	1.0	—	8.8	1.91	0.17	5.	—	3.0	0.68	0.06	1.8	—	48.7	19.00	0.70	477.5
2303	0.8	—	6.6	2.06	0.16	8	—	1.2	0.36	0.03	1.4	—	50.3	19.49	0.74	479.4

TIME	CUMULATIVE RAINFALL (inches)	CUMULATIVE DISCHARGE (ft^3)
2108	0.18	550
2117	0.25	10,000
2138	0.28	22,000
2203	0.28	25,000
2233	0.28	30,000
2303	0.28	34,000

NOTES : VALUES LISTED AS NH_3-N ARE ACTUALLY TOTAL N

HART LANE

EVENT 34 9/14/81



DATE : 9/15/81

SITE : HART LANE

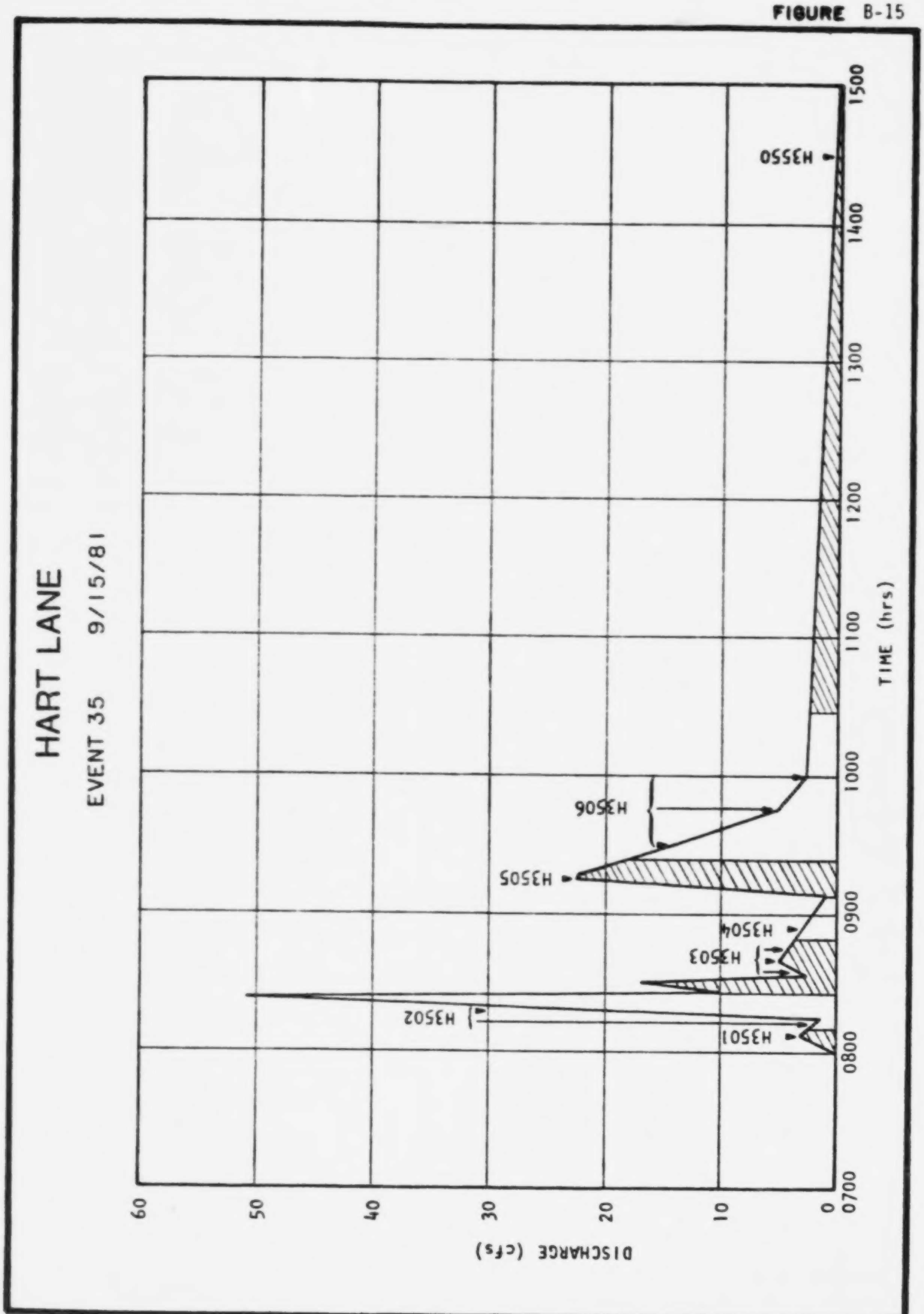
TABLE B-15

EVENT NO. : 35

TIME	INST DIS (cfs)	INST POLL CONC (mg/l)					AVG MASS FLUX (lb/hr)					CUM MASS DISCHARGED (lbs)				
		COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS
0808	2.5	—	9.5	8.56	0.32	12.	—	2.4	1.92	0.06	2.4	—	0.4	0.32	0.01	0.4
0818	28.0	—	14.4	13.20	0.42	46	—	56.1	51.42	1.77	179.3	—	16.3	14.89	0.51	51.2
0843	4.5	—	12.3	10.40	0.38	238.	—	16.9	14.22	0.51	325.4	—	22.2	19.87	0.69	165.1
0853	2.5	—	10.7	7.57	0.32	108.	—	6.4	2.97	0.32	42.0	—	24.0	20.71	0.78	177
0915	21.0	—	11.9	2.27	0.29	32.	—	38.0	7.23	0.93	102.0	—	35.4	22.88	1.06	208
1000	3.0	—	11.3	2.29	0.24	20.	—	13.9	2.82	0.30	24.7	—	51.2	26.08	1.40	236
1420	0.5	—	7.4	2.06	0.06	5.	—	2.5	0.70	0.02	1.7	—	63.7	29.57	1.50	245.

TIME	CUMULATIVE RAINFALL (inches)	CUMULATIVE DISCHARGE (ft^3)
0808	-	560
0818	-	17,000
0843	-	27,000
0853	-	28,000
0915	-	45,000
1000	-	70,000
1420	-	95,000

NOTES : VALUES REPORTED AS NH_3-N (ABOVE)
ARE ACTUALLY TOTAL-N



HART LANE

EVENT 35 9/15/81

DATE : 4/17/81

SITE : ROLLINGWOOD

TABLE B-16

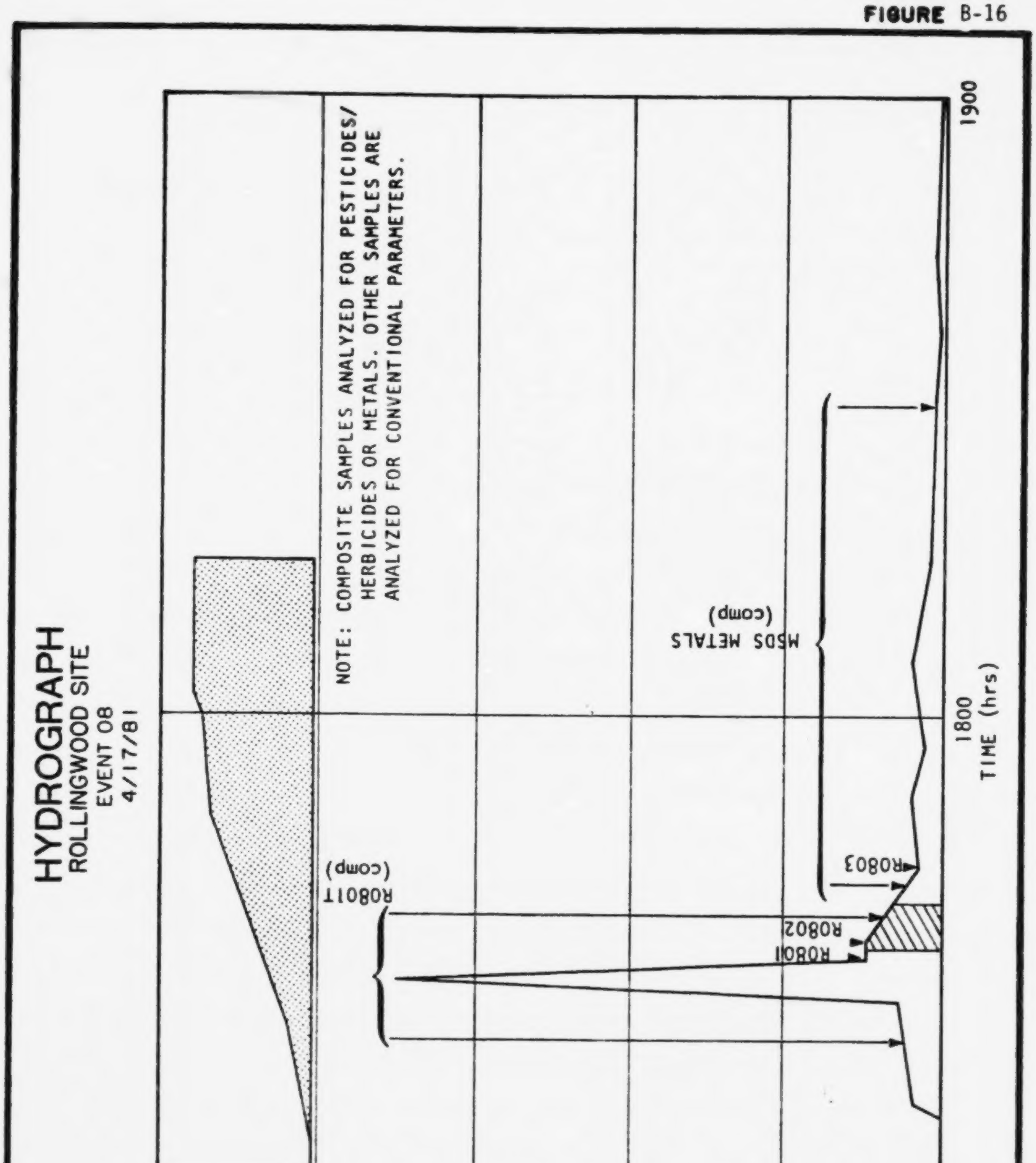
EVENT NO. : 08

TIME	INST DIS (cfs)	INST POLL CONC (mg/l)					AVG MASS FLUX (lb/hr)					CUM MASS DISCHARGED (lbs)				
		COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS
1738	0.8	107	28.0	2.21	0.45	524	30.4	8.1	0.64	0.14	148.	8.6	2.3	0.18	0.04	42.
1741	0.5	160	446.0	2.24	0.62	752	23.5	65.4	0.34	0.09	110.	11.3	9.9	0.22	0.05	55.
1745	0.3	80	16.0	1.93	0.48	224	3.8	0.8	0.09	0.02	10.6	16.3	10.9	0.34	0.08	69

TIME	CUMULATIVE RAINFALL (inches)	CUMULATIVE DISCHARGE (ft^3)
1738	0.10	1,600
1741	0.34	1,750
1745	0.41	2.800

NOTES :

FIGURE B-16



HYDROGRAPH
ROLLINGWOOD SITE
EVENT 08
4/17/81

NOTE: COMPOSITE SAMPLES ANALYZED FOR PESTICIDES/HERBICIDES OR METALS. OTHER SAMPLES ARE ANALYZED FOR CONVENTIONAL PARAMETERS.

DATE : 5/16/81
SITE : ROLLINGWOOD
EVENT NO. : 14

TABLE B-17

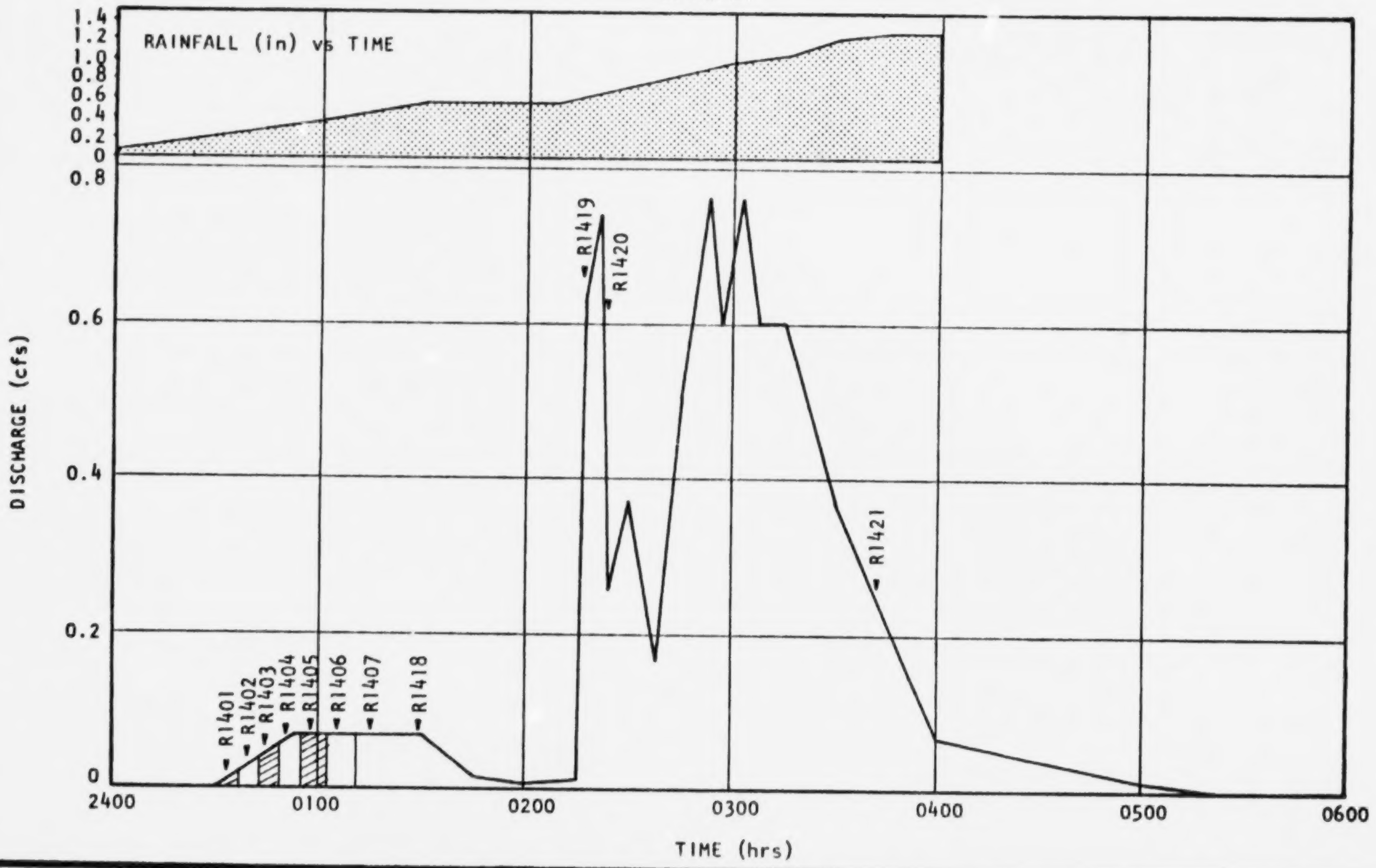
TIME	INST DIS (cfs)	INST POLL CONC (mg/l)					AVG. MASS FLUX (lb/hr)					CUM MASS DISCHARGED (lbs)				
		COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS
0033	0.1	152.	22.3	2.28	0.20	42.	0.6	0.07	0.01	—	0.1	0.09	0.01	0.001	~0	0.02
0040	0.1	80.	18.5	2.06	0.19	32.	0.7	0.2	0.01	—	0.3	0.15	0.02	0.002	~0	0.04
0045	0.1	76	20.1	2.60	0.24	44	0.9	0.2	0.03	—	0.5	0.21	0.04	0.004	~0	0.08
0053	0.2	42.	(15.)	2.80	0.29	40	0.6	0.2	0.04	0.01	0.6	0.29	0.07	0.009	.001	0.16
0100	0.2	38	(15)	2.00	0.17	29.	0.7	0.3	0.03	—	0.5	0.39	0.11	0.014	.001	0.24
0112	0.2	228.	(15)	2.60	0.17	44.	3.2	0.2	0.03	—	0.6	0.87	0.14	0.019	.001	0.33
0118	0.1	76.	18.7	2.36	0.17	64	1.0	0.2	0.03	—	0.9	1.02	0.18	0.024	.001	0.46
0128	0.1	84.	16.9	1.25	0.34	378.	0.5	0.1	0.03	<.01	2.4	1.34	0.25	0.029	.002	1.92
0218	0.7	38.	9.0	0.90	0.21	80	2.7	0.6	0.06	0.02	5.7	2.22	0.46	0.050	.007	3.77
0220	0.7	42.	7.2	0.97	0.14	33.	10.4	1.8	0.24	0.04	8.2	8.73	1.58	0.200	.029	8.88
0340	0.1	114.	8.9	1.03	0.20	47.	11.6	0.9	0.10	0.02	48	35.3	3.7	0.44	.08	20.

TIME	CUMULATIVE RAINFALL (inches)	CUMULATIVE DISCHARGE (ft^3)
0033	0.20	9
0040	0.30	68
0045	0.35	75
0053	0.39	79
0100	0.40	120
0112	0.48	170
0118	0.52	280
0128	0.60	290
0218	0.60	400
0220	0.62	450
0340	1.20	7,000

NOTES : ALL CONCENTRATION VALUES IN PARENTHESES ARE ESTIMATES

FIGURE B-17

HYDROGRAPH
ROLLINGWOOD SITE
EVENT 14
5/16/81



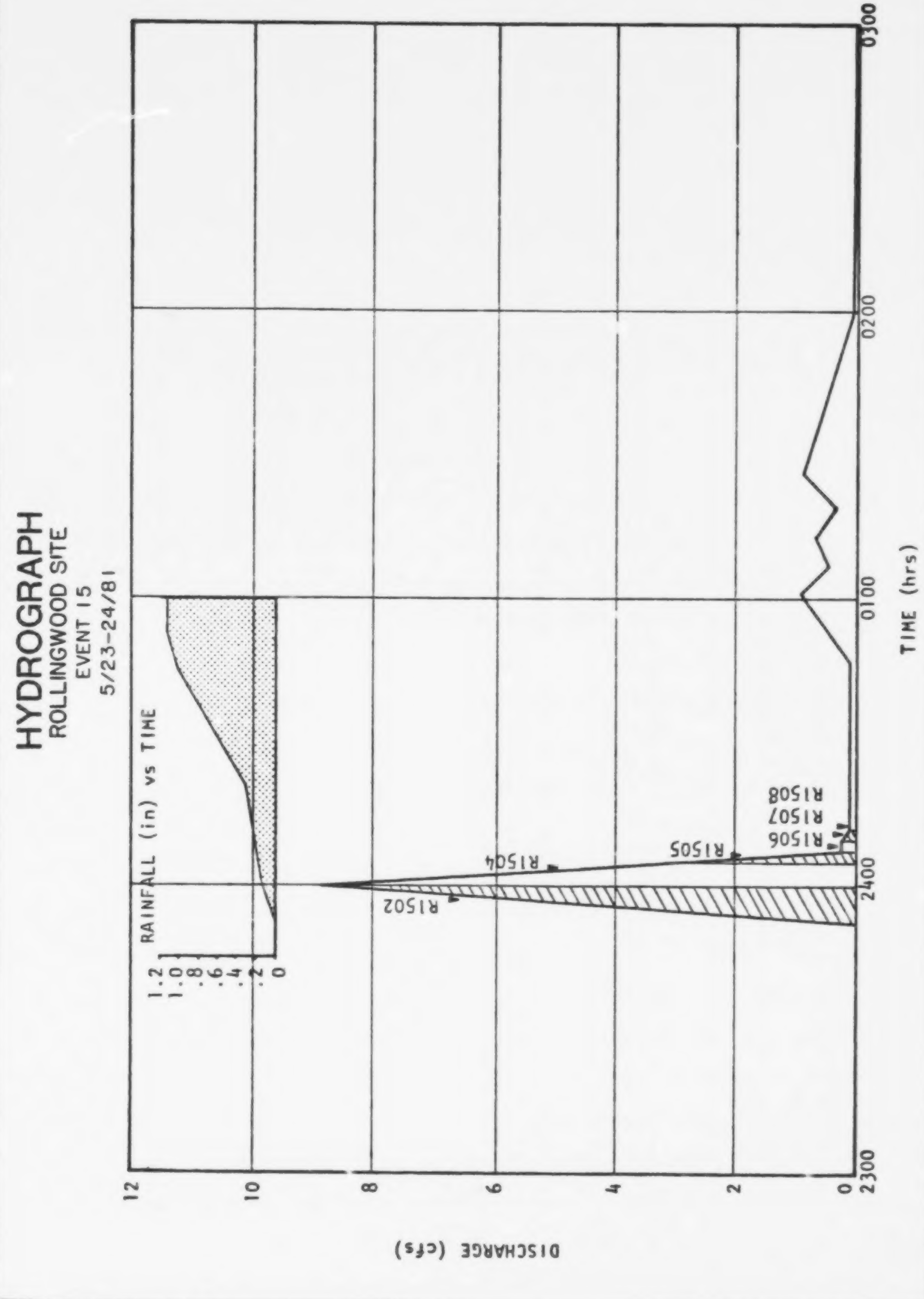
DATE : 5/23 - 5/24/81
SITE : ROLLINGWOOD
EVENT NO. : 15

TABLE B-18

TIME	INST DIS (cfs)	INST POLL CONC(mg/l)					AVG MASS FLUX (lb/hr)					CUM MASS DISCHARGED (lbs)				
		COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS
2355 (5/16)	6.5	202	53.6	1.93	0.55	425	149.1	39.5	1.40	0.40	313.	22.4	5.9	0.21	0.06	47
0005	5.0	190.	43.0	3.10	0.71	900	199.1	45.1	3.20	0.80	943.	37.3	9.3	0.45	0.12	118
0007	2.0	76	11.5	0.96	0.15	124.	20.5	3.2	0.27	—	33	38.1	9.4	0.46	0.12	119.
0010	0.3	76.	13.3	1.05	0.20	75	8.5	1.5	0.12	0.04	8.4	38.3	9.4	0.46	0.12	119
0013	0.2	95.	19.8	1.39	0.37	356	4.3	0.9	0.08	—	16.0	38.4	9.4	0.46	0.12	119
0015	0.1	76.	15.7	0.95	0.32	220	3.4	0.7	0.04	—	9.9	38.5	9.4	0.46	0.12	119
0200	0.8	(60.)	(14.0)	(1.00)	(0.30)	(100.)	3.3	0.8	0.05	0.02	5.6	47.7	11.6	0.61	0.17	134

TIME	CUMULATIVE RAINFALL (inches)	CUMULATIVE DISCHARGE (ft^3)
2355	0.10	1,950
0005	0.20	2,200
0007	0.21	2,500
0010	0.22	2,600
0013	0.23	2,700
0015	0.24	2,800
0200	1.20	8,000

NOTES : ALL CONCENTRATION VALUES IN PARENTHESES ARE ESTIMATES


HYDROGRAPH
ROLLINGWOOD SITE
EVENT 15
5/23-24/81
RAINFALL (in) vs TIME
1.2
1.0
.8
.6
.4
.2
0
DISCHARGE (cfs)
12
10
8
6
4
2
0
2300
2400
0100
0200
0300
TIME (hrs)
R1502
R1504
R1505
R1506
R1507
R1508

DATE : 6/01/81
SITE : ROLLINGWOOD
EVENT NO. : 18

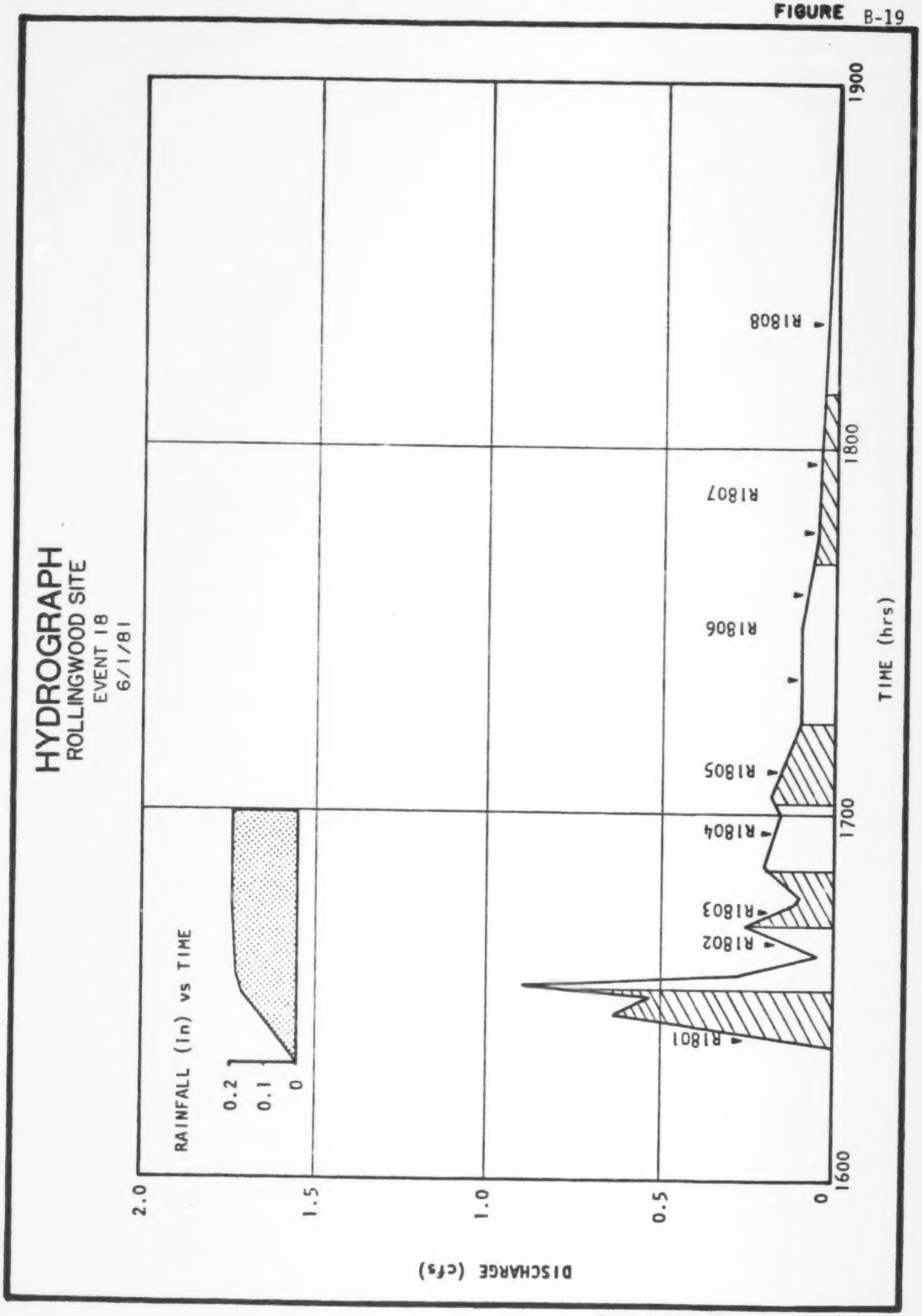
TABLE B-19

TIME	INST DIS (cfs)	INST POLL CONC (mg/l)					AVG. MASS FLUX (lb/hr)					CUM MASS DISCHARGED (lbs)				
		COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS
1618	0.20	107.	21.8	0.85	0.31	182.	9.8	2.3	0.08	0.03	15.8	1.3	0.3	0.01	0.004	2.1
1638	0.10	148.	16.4	1.00	0.24	210.	4.7	0.4	0.43	0.01	6.4	2.4	0.4	0.11	0.006	3.6
1645	0.15	46.	12.6	0.54	0.22	201.	1.8	0.6	0.02	0.01	6.6	2.7	0.5	0.11	0.007	4.7
1658	0.17	38.	17.7	0.58	0.20	292.	1.6	0.5	0.06	0.01	12.5	3.0	0.6	0.12	0.009	7.0
1708	0.15	23.	21.2	0.85	0.34	196.	0.5	0.5	0.06	0.01	6.0	3.1	0.7	0.13	0.011	8.1
1738	0.07	8.	24.1	1.03	0.28	244.	0.2	0.4	0.02	0.01	5.1	3.2	0.9	0.14	0.014	10.5
1758	0.03	38.	12.6	1.01	0.23	126.	0.2	0.2	0.01	—	1.2	3.3	1.0	0.14	0.015	11.0
1822	0.02	38.	10.2	0.81	0.14	7.	0.1	0.1	0.01	—	0.1	3.4	1.0	0.14	0.015	11.1

TIME	CUMULATIVE RAINFALL (inches)	CUMULATIVE DISCHARGE (ft^3)
1618	0.02	190
1638	0.20	300
1645	0.20	390
1658	0.20	510
1708	0.20	600
1738	0.20	700
1758	0.20	880
1822	0.20	890

NOTES :

FIGURE B-19


HYDROGRAPH
ROLLINGWOOD SITE
EVENT 18
6/1/81
RAINFALL (in) vs TIME
0.2
0.1
0
DISCHARGE (cfs)
2.0
1.5
1.0
0.5
0
1600
1700
1800
1900
TIME (hrs)
R1801
R1802
R1803
R1804
R1805
R1806
R1807
R1808

DATE : 6/02/81

SITE : ROLLINGWOOD

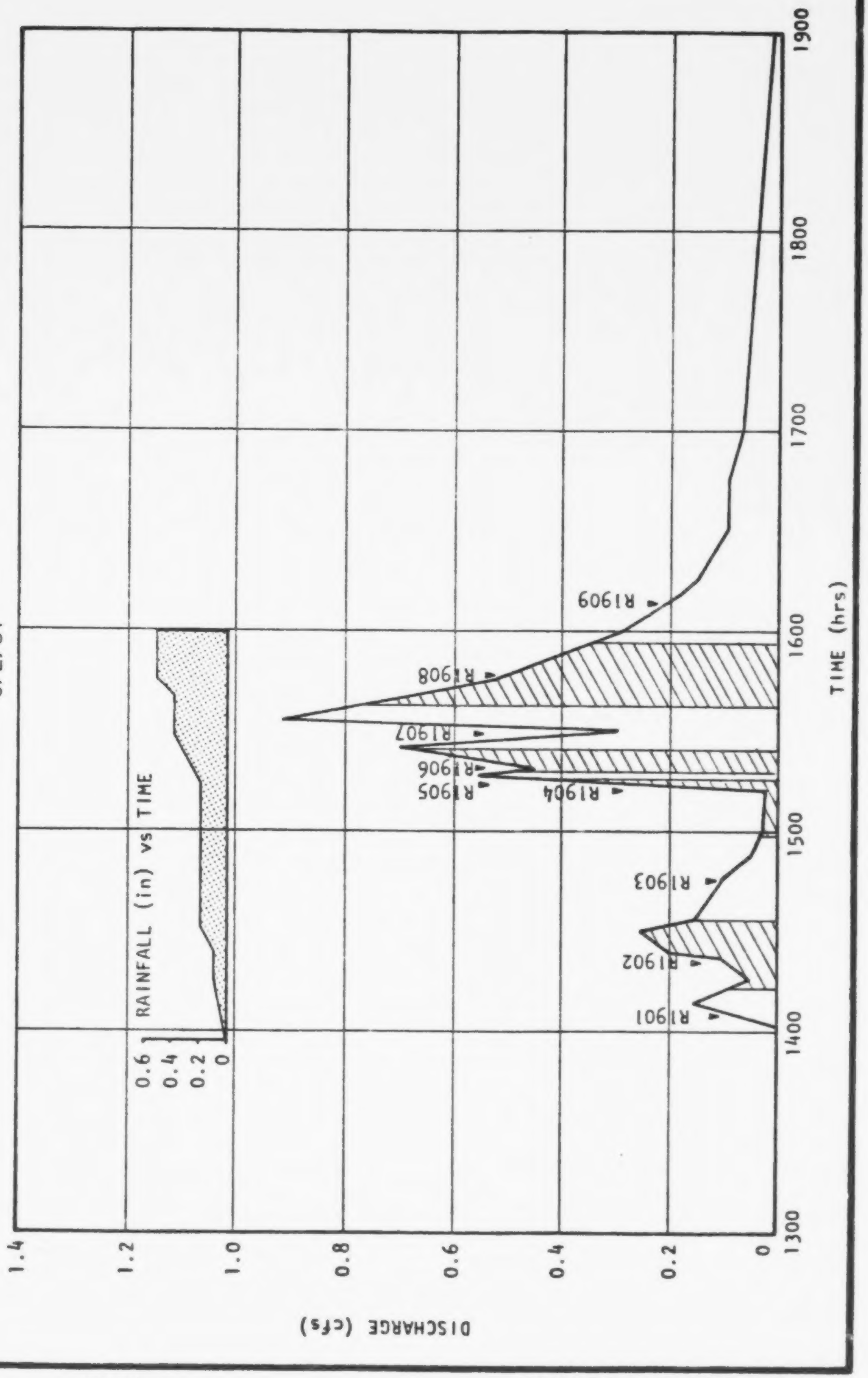
EVENT NO. : 19

TABLE B-20

TIME	INST DIS (cfs)	INST POLL CONC (mg/l)					AVG. MASS FLUX (lb/hr)					CUM MASS DISCHARGED (lbs)				
		COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS
1402	0.06	95.	47.0	4.00	0.32	164	2.1	1.0	0.11	0.01	3.6	0.4	0.2	0.02	0.001	0.7
1421	0.10	69.	42.8	1.76	0.22	190.	2.2	1.4	0.05	0.01	6.0	1.2	0.7	0.04	0.004	3.0
1445	0.10	57.	35.5	1.87	0.17	178.	1.0	0.7	0.03	<0.01	3.1	1.6	1.0	0.05	0.005	4.2
1510	0.20	11.	19.8	0.85	0.05	31	0.1	0.2	0.01	<.01	0.4	1.6	1.1	0.05	0.006	4.3
1513	0.52	30.	26.5	1.20	0.19	240.	3.5	3.2	0.15	0.02	28.5	1.8	1.3	0.06	0.007	6.2
1517	0.42	76.	37.8	2.50	0.42	316.	10.4	5.1	0.32	0.06	42.4	3.1	1.9	0.10	0.014	11.5
1530	0.50	30.	22.3	0.90	0.20	1280.	4.5	3.4	0.12	0.03	194	4.2	2.8	0.13	0.022	60.0
1548	0.48	19.	30.5	1.33	0.09	48.	2.1	3.4	0.14	0.01	5.3	4.8	3.8	0.17	0.025	61.5
1606	0.19	23.	26.3	0.76	0.08	7.	0.3	0.4	0.01	<0.01	0.1	5.8	5.0	0.20	0.029	61.8

TIME	CUMULATIVE RAINFALL (inches)	CUMULATIVE DISCHARGE (ft^3)
1402	0.02	68
1421	0.10	280
1445	0.20	380
1510	0.20	450
1513	0.20	500
1517	0.20	800
1530	0.40	1,750
1548	0.58	1,950
1606	0.58	2,500

NOTES :



HYDROGRAPH
ROLLINGWOOD SITE
EVENT 19
6/2/81

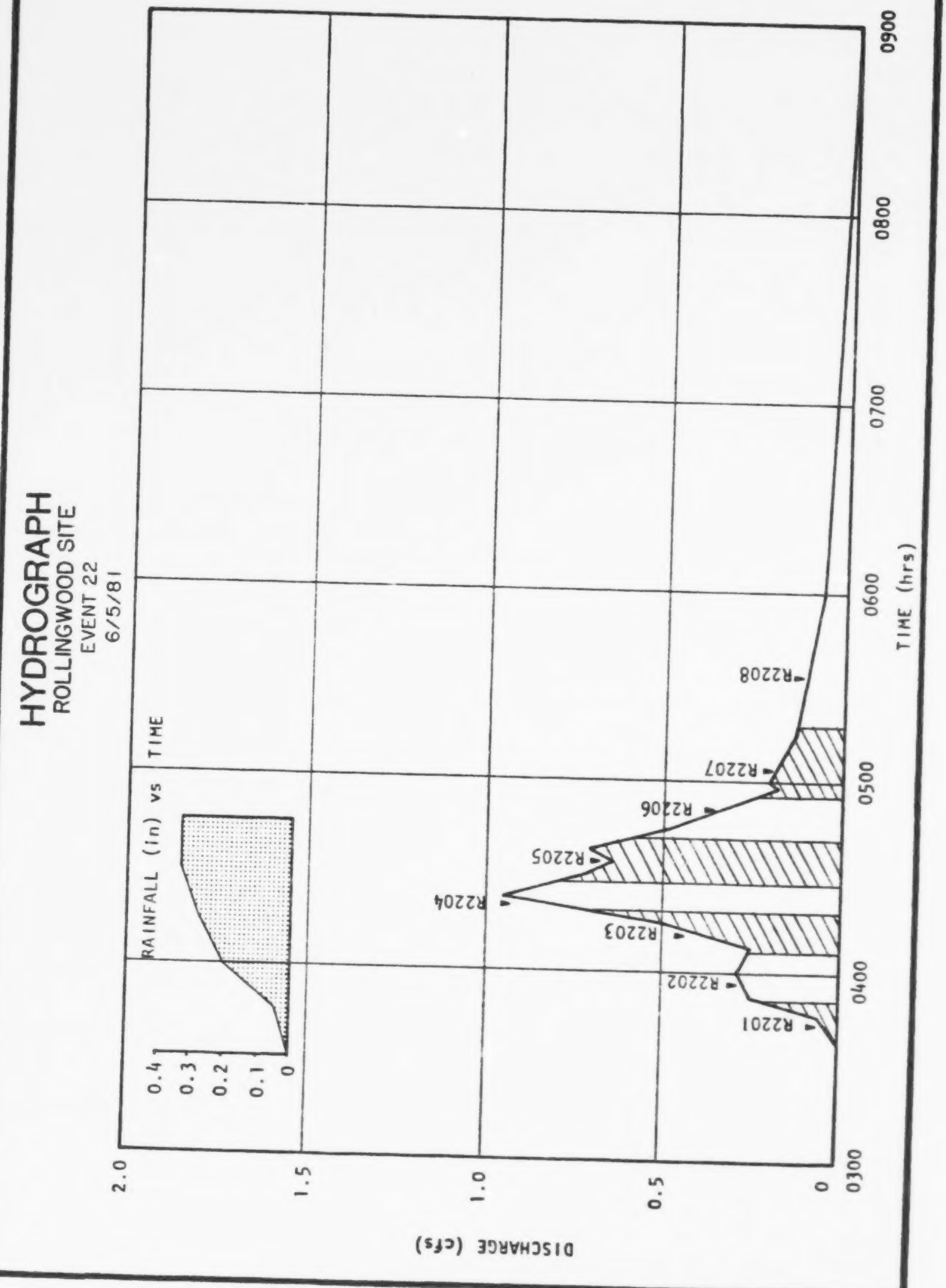
DATE : 6/05/81
SITE : ROLLINGWOOD
EVENT NO. : 22

TABLE B-21

TIME	INST DIS (cfs)	INST POLL CONC (mg/l)					AVG MASS FLUX (lb/hr)					CUM MASS DISCHARGED (lbs)				
		COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS
0345	0.06	46	23.1	0.76	0.09	41	0.8	0.4	0.01	—	0.8	0.2	0.1	0.003	~0	0.2
0400	0.15	46	13.3	0.61	0.07	27	1.8	0.4	0.02	<.01	0.9	0.6	0.2	0.008	0.001	0.4
0413	0.34	38	12.6	0.79	0.11	39.	2.9	1.1	0.06	0.01	2.9	1.1	0.4	0.019	0.002	0.9
0419	0.93	42	9.4	1.03	0.15	82	8.6	1.7	0.22	0.03	17.1	2.6	0.7	0.057	0.008	3.9
0432	0.67	46	9.3	0.63	0.14	25.	6.9	1.5	0.09	0.02	3.6	4.5	1.1	0.083	0.014	4.9
0452	0.28	15.	10.1	0.90	0.15	20.	1.2	0.8	0.07	0.01	1.6	4.8	1.3	0.100	0.017	5.3
0503	0.19	46.	10.8	0.71	0.14	17	1.5	0.3	0.02	0.01	0.6	5.3	1.4	0.108	0.019	5.5
0533	0.09	38	10.3	0.57	0.14	10	0.3	0.1	0.01	< .01	0.1	6.0	1.6	0.119	0.022	5.7

TIME	CUMULATIVE RAINFALL (inches)	CUMULATIVE DISCHARGE (ft³)
0345	0.05	58
0400	0.20	130
0413	0.24	180
0419	0.25	200
0432	0.30	1,300
0452	0.35	2,000
0503	0.35	2,200
0533	0.35	2,600

NOTES :



HYDROGRAPH
ROLLINGWOOD SITE
EVENT 22
6/5/81

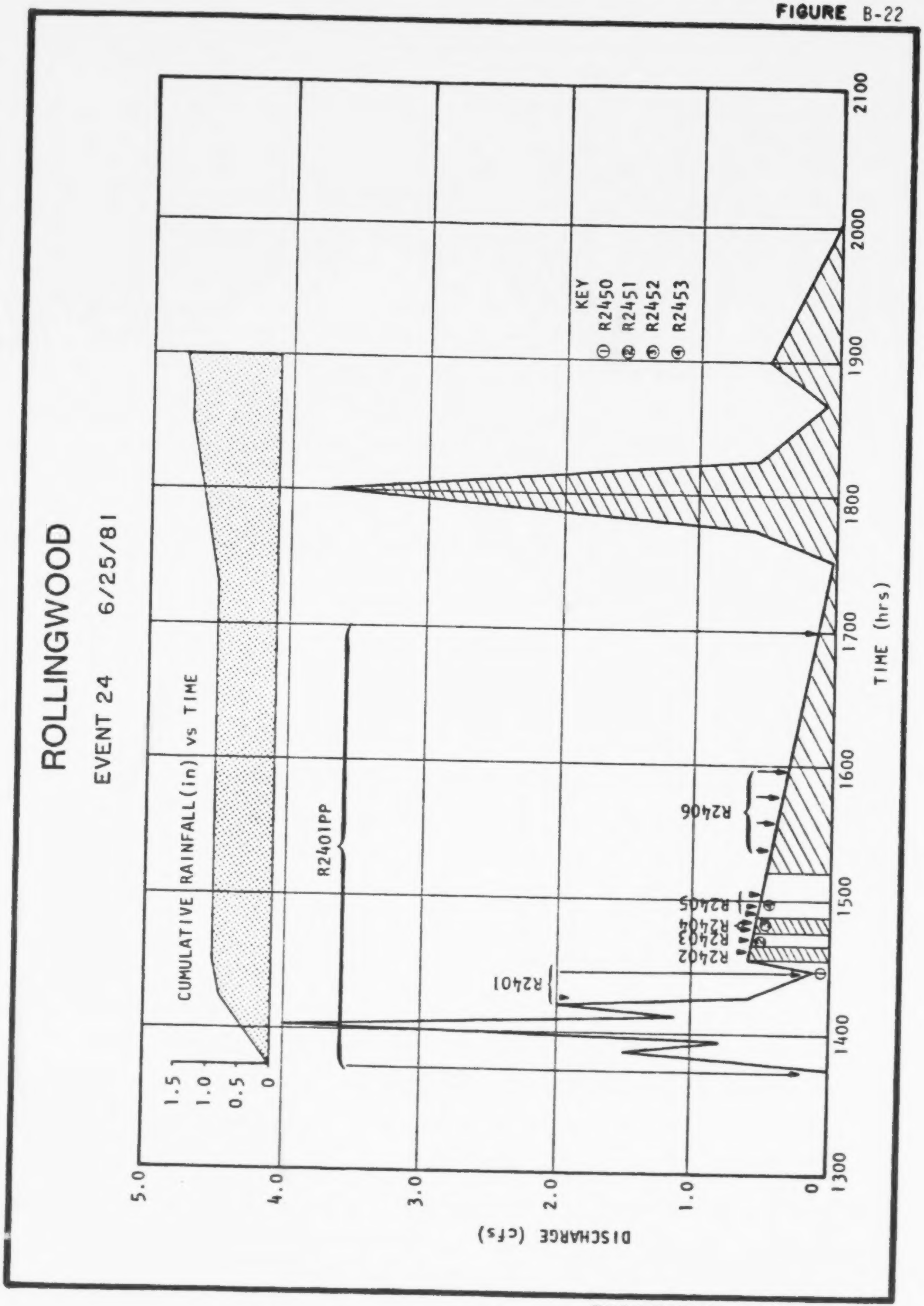
DATE : 6/25/81
SITE : ROLLINGWOOD
EVENT NO. : 24

TABLE B-22

TIME	INST DIS (cfs)	INST POLL CONC (mg/l)					MASS FLUX (lb/hr)					CUM MASS DISCHARGED (lb)				
		COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS
1425	0.2	186.	46.6	1.26	0.35	344.	53.	10.62	.29	.08	78.4	35.3	8.85	.24	.07	65.3
1440	0.6	50.	15.3	1.50	0.24	73.	2.	.56	.13	—	5.3	35.9	9.02	.26	.07	66.1
1443	0.6	29.	15.3	0.87	0.19	28.	1.7	.94	.17	—	3.4	36.1	9.13	.27	.07	66.3
1447	0.5	32.	12.3	0.87	0.19	18.	1.1	.53	.08	.08	1.5	36.4	9.27	.28	.08	66.5
1459	0.5	64.	14.0	0.90	0.19	21.	6.0	1.18	.08	—	1.9	39.1	9.84	.32	.08	67.4
1545	0.4	36.	11.4	0.79	0.16	20.	3.2	.97	.07	.02	1.7	44.7	11.62	.44	.11	70.5

TIME	CUMULATIVE RAINFALL (inches)	CUMULATIVE DISCHARGE (ft^3)
1425	0.70	-
1440	0.70	-
1443	0.70	-
1447	0.70	-
1459	0.70	-
1545	0.70	-

NOTES :


ROLLINGWOOD
EVENT 24 6/25/81
CUMULATIVE RAINFALL (in) vs TIME
1.5
1.0
0.5
0
DISCHARGE (cfs)
5.0
4.0
3.0
2.0
1.0
0
TIME (hrs)
1300
1400
1500
1600
1700
1800
1900
2000
2100
R2401PP
R2401
R2402
R2403
R2404
R2405
R2406
KEY
① R2450
② R2451
③ R2452
④ R2453

DATE : 7/05/81

SITE : ROLLINGWOOD

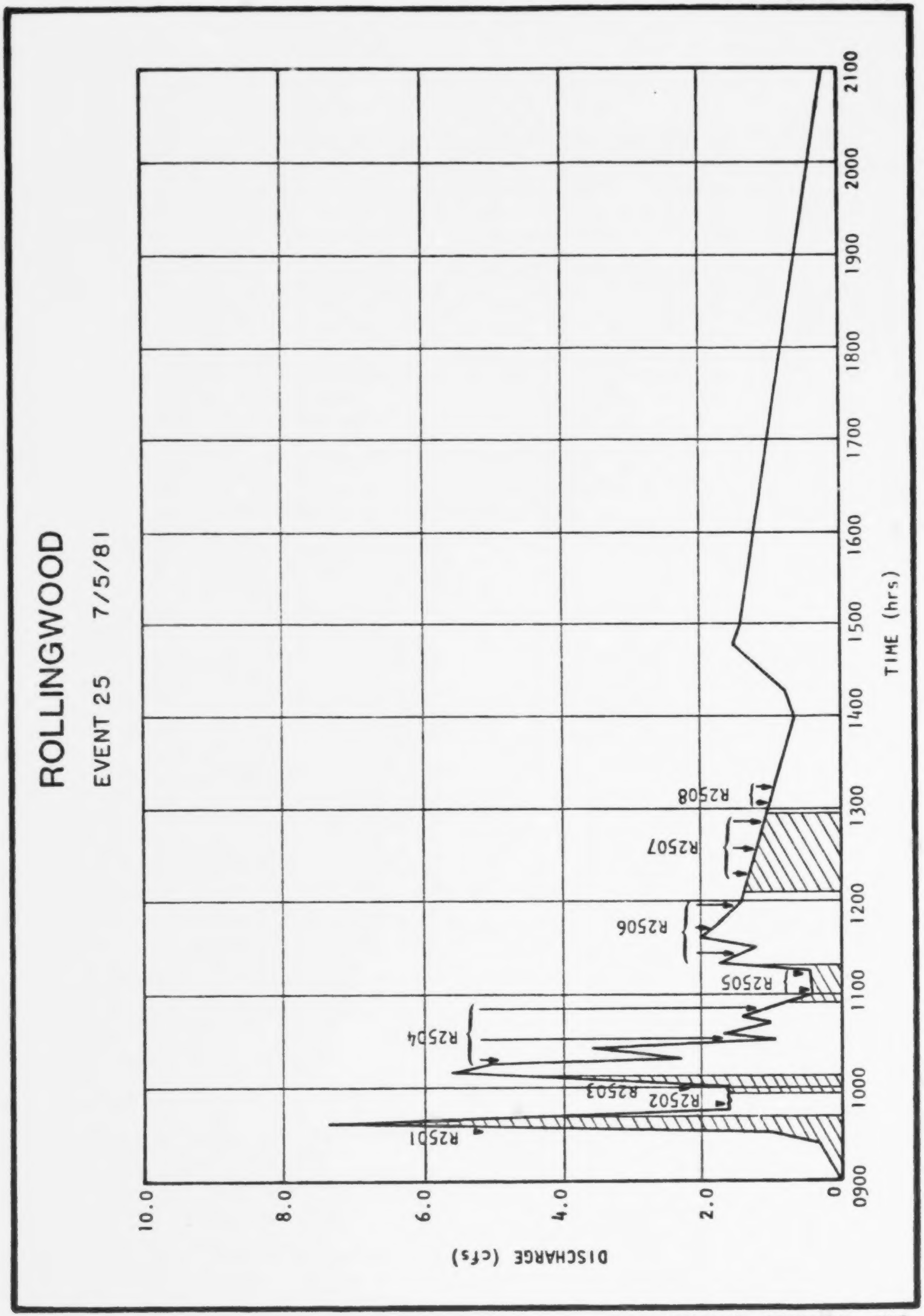
EVENT NO. : 25

TABLE B-23

TIME	INST DIS (cfs)	INST POLL CONC (mg/l)					AVG MASS FLUX (lb/hr)					CUM MASS DISCHARGED (lbs)				
		COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS
0930	0.50	282	68.4	1.86	0.43	330	7.8	1.8	0.05	0.02	9.2	5.1	1.2	0.03	0.01	6.0
0945	0.18	107	32.6	1.17	0.47	1635	4.4	1.2	0.04	0.04	67.2	6.2	1.5	0.04	0.02	22.8
1003	0.20	64	19.6	0.04	0.62	268	2.7	0.9	—	0.04	14.7	6.8	1.7	0.04	0.03	25.5
1048	0.10	54	19.4	3.36	0.93	146	2.8	1.0	0.18	0.05	7.9	9.0	2.5	0.18	0.07	31.6
1116	0.05	36	15.0	1.33	0.49	475	0.4	0.2	0.02	—	4.4	9.2	2.6	0.19	0.07	33.7
1159	0.14	25	10.8	0.77	0.22	69	1.0	0.4	0.03	0.01	2.5	9.9	2.9	0.21	0.08	35.5
1243	0.11	29	10.2	0.46	0.18	72	0.8	0.3	0.01	—	2.1	10.5	3.1	0.22	0.08	37.1
1315	0.09	36	10.4	0.81	0.18	87	2.1	0.6	0.05	0.01	5.0	15.0	4.4	0.32	0.10	47.9

TIME	CUMULATIVE RAINFALL (inches)	CUMULATIVE DISCHARGE (ft³)
0930	-	290
0945	-	600
1003	-	700
1048	-	1,400
1116	-	1,700
1159	-	2,000
1243	-	2,500
1315	-	3,000

NOTES :


ROLLINGWOOD
EVENT 25 7/5/81
DISCHARGE (cfs)
10.0
8.0
6.0
4.0
2.0
0
0900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
TIME (hrs)
R2501
R2502
R2503
R2504
R2505
R2506
R2507
R2508

DATE : 8/07/81

SITE : ROLLINGWOOD

EVENT NO. : 31

TABLE B-24

TIME	INST DIS (cfs)	INST POLL CONC (mg/l)					AVG MASS FLUX (lb/hr)					CUM MASS DISCHARGED (lbs)				
		COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS
1514	0.09	357	98.6	3.80	0.50	84	3.8	0.9	0.05	<.01	0.9	0.8	0.2	0.01	0.001	0.2
1516	0.04	268.	105.5	3.48	0.32	236.	3.4	1.1	0.11	0.01	5.7	1.1	0.3	0.01	0.001	0.5
1522	0.09	286.	85.3	3.80	0.36	232.	5.6	1.8	0.09	0.01	4.4	3.0	0.9	0.04	0.003	2.0
1550	0.15	82.	55.3	1.60	0.11	140.	2.6	1.6	0.06	<.01	4.2	3.8	1.4	0.06	0.004	3.3
1606	0.08	71.	27.0	1.44	0.25	82.	1.5	0.4	0.04	<.01	1.5	4.2	1.5	0.07	0.005	3.7
1623	0.05	43.	26.6	1.15	0.18	32.	0.7	0.7	<.01	<.01	0.7	4.3	1.6	0.07	0.005	3.8
1627	0.04	36.	87.1	1.03	0.16	26.	0.2	0.5	<.01	<.01	0.2	4.4	1.9	0.07	0.005	3.9

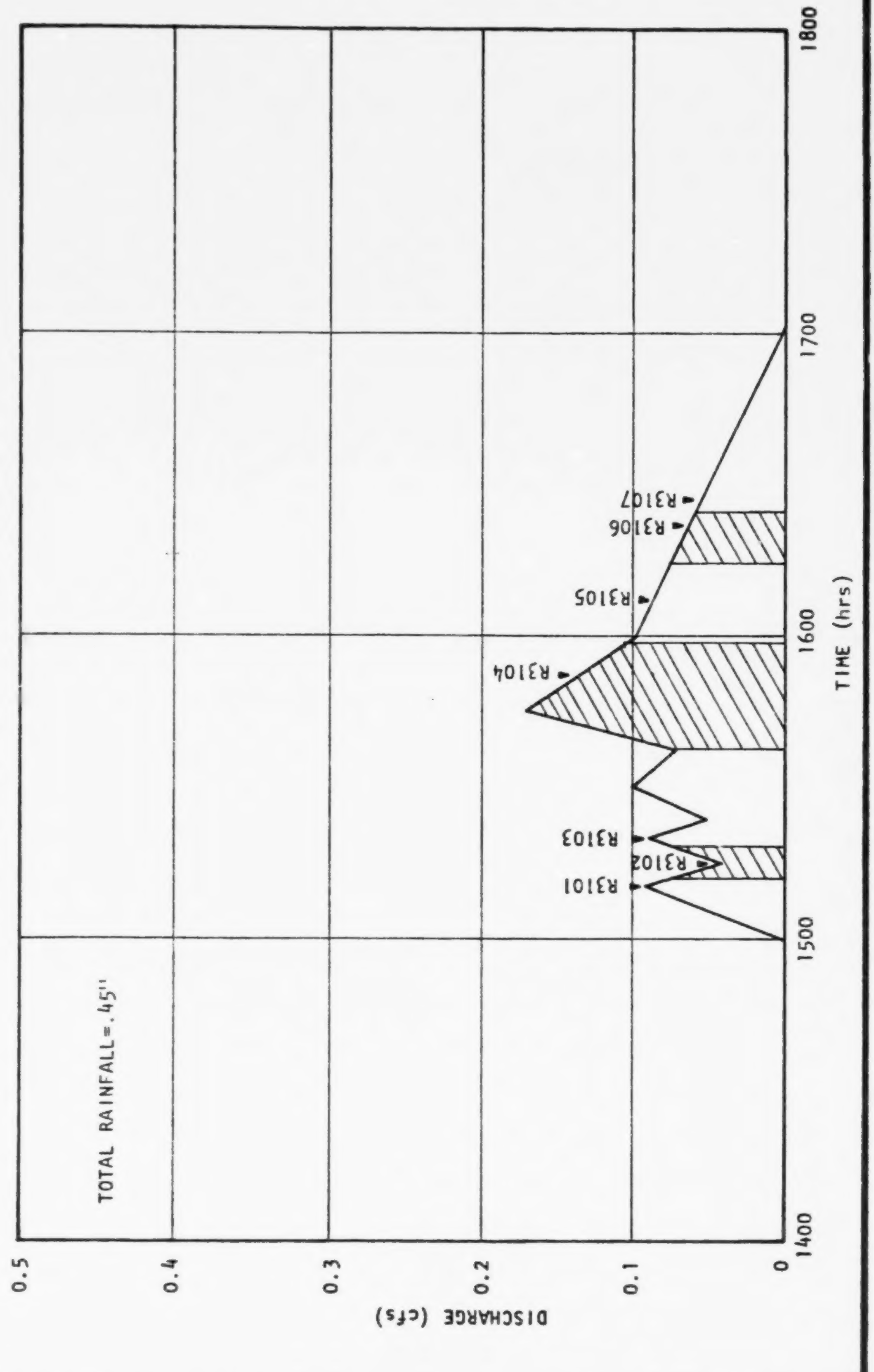
TIME	CUMULATIVE RAINFALL (inches)	CUMULATIVE DISCHARGE (ft^3)
1514	-	37
1516	-	41
1522	-	290
1550	-	330
1606	-	380
1623	-	400
1627	0.45	410

NOTES :

FIGURE B-24

ROLLINGWOOD

EVENT 31 8/7/81



DATE : 3/07/81

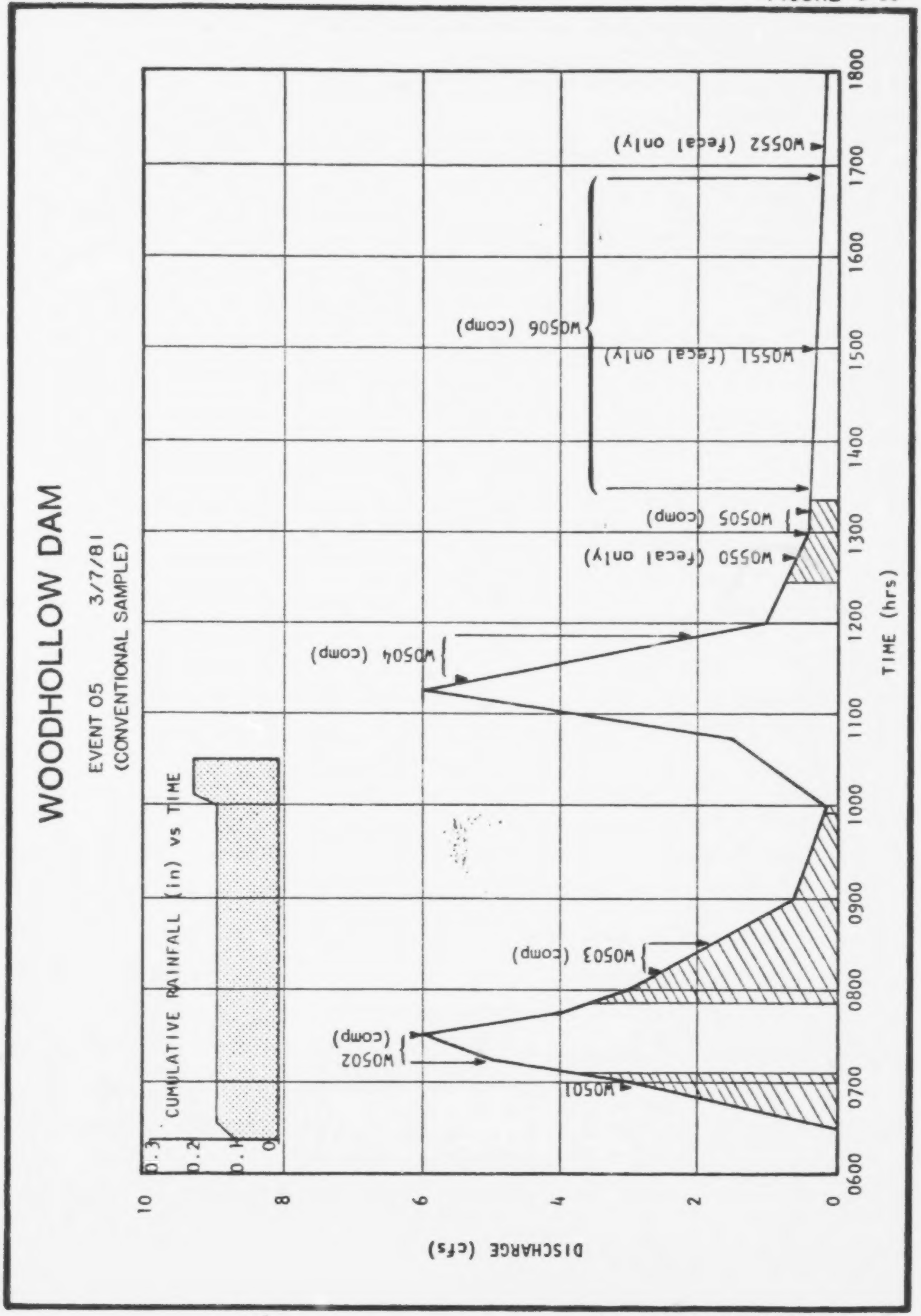
SITE : WOODHOLLOW DAM (DAM CLOSED)

TABLE B-25

EVENT NO. : 05

TIME	INST DIS (cfs)	INST POLL CONC (mg/l)					AVG. MASS FLUX (lb/hr)					CUM MASS DISCHARGED (lbs)				
		COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS
0700	2.5	(30.)	(7.6)	(1.00)	0.17	32.	11.7	3.0	0.39	0.06	12.3	7.4	1.9	0.25	0.04	7.8
0730	6.0	23.	7.7	0.91	0.15	21.	24.1	8.1	0.96	0.16	22.0	25.5	8.0	0.97	0.16	24.3
0830	1.4	19.	7.4	0.85	0.14	12.	8.0	3.1	0.36	0.06	5.0	36.5	12.3	1.46	0.24	31.2
1153	1.8	38.	8.5	0.69	0.14	6.	15.6	3.5	0.28	0.06	2.4	84.2	20.8	2.33	0.42	38.7
1315	0.4	34.	10.0	0.85	0.14	11.	3.2	0.9	0.08	0.01	1.0	87.6	21.8	2.41	0.43	39.8
1653	0.2	38.	8.6	0.90	0.17	7.	1.0	0.2	0.02	0.00	0.2	91.6	22.7	2.50	0.45	40.5

NOTES : VALUES IN PARENTHESES ARE ESTIMATES.



WOODHOLLOW DAM

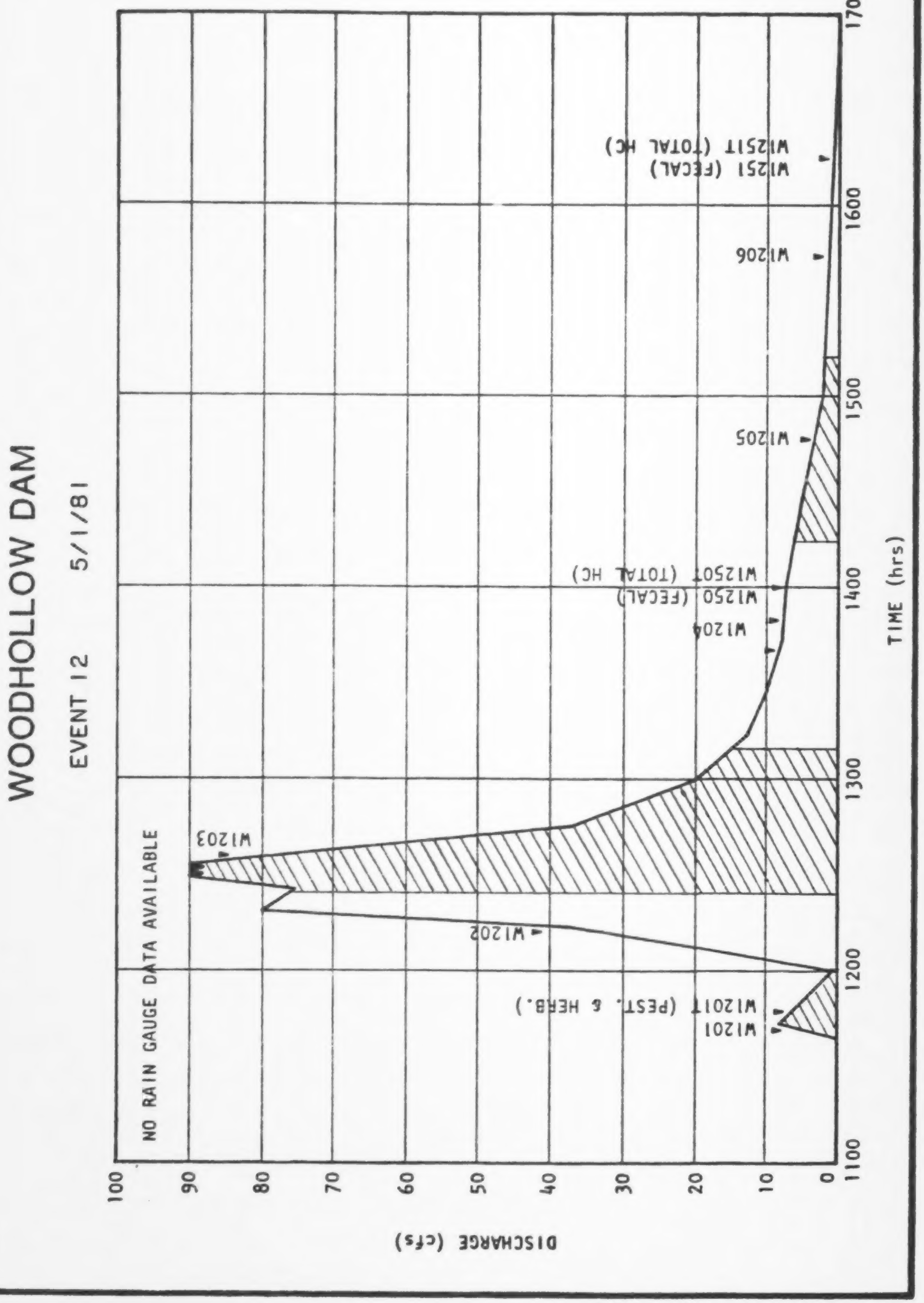
EVENT 05 3/7/81

(CONVENTIONAL SAMPLE)

DATE : 5/01/81
SITE : WOODHOLLOW DAM (DAM CLOSED) TABLE B-26
EVENT NO. : 12

TIME	INST DIS (cfs)	INST POLL CONC (mg/l)					AVG MASS FLUX (lb/hr)					CUM MASS DISCHARGED (lbs)				
		COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS
1145	8.	42.	10.6	1.23	0.16	25.	60.3	15.2	1.76	0.24	34.7	22.6	5.7	0.66	0.09	13.
1215	42.	38.	10.8	1.47	0.20	39.	305.4	86.8	11.82	1.50	313.4	160.	44.8	5.98	0.81	154
1238	80.	46	17.3	2.73	0.37	170.	423.8	159.4	25.15	3.41	1566.	477.9	164.4	24.84	3.37	1329
1353	7.	38.	10.8	3.33	0.37	72.	76.2	21.7	6.68	0.74	144.4	563.6	188.8	32.35	4.20	1491.
1445	3.	38.	11.8	1.33	0.32	55.	22.1	6.9	0.77	0.18	31.9	584.0	195.1	33.06	4.37	1521.
1545	1.	38.	10.3	2.27	0.34	48.	6.5	1.8	0.39	0.06	9.2	592.2	197.3	33.55	4.44	1531.

NOTES :



WOODHOLLOW DAM

EVENT 12 5/1/81

DATE : 5/02/81

SITE : WOODHOLLOW DAM (DAM CLOSED) TABLE B-27

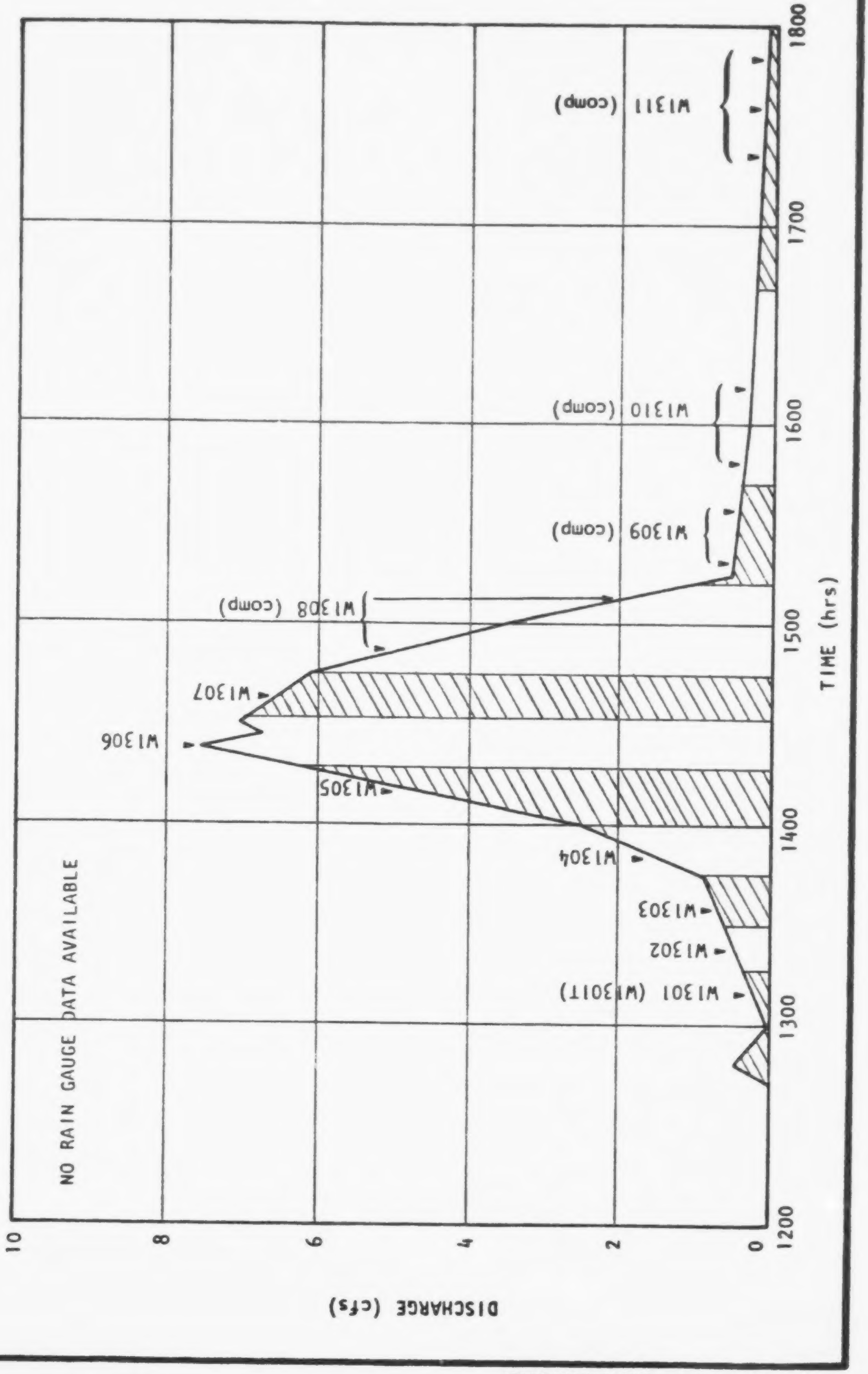
EVENT NO. : 13

TIME	INST DIS (cfs)	INST POLL CONC					MASS FLUX (lb/hr)					CUM MASS DISCHARGED				
		COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS
1308	0.2	23.	19.8	1.88	0.27	12.	1.0	0.8	0.08	0.02	0.6	0.5	0.4	0.04	0.01	0.3
1323	0.5	15	22.6	1.62	0.24	21	0.9	2.8	0.20	0.04	2.4	0.9	1.1	0.09	0.02	0.9
1338	0.7	15	17.6	2.20	0.28	140.	2.2	2.6	0.32	0.04	20.3	1.4	1.7	0.17	0.03	6.0
1353	1.4	38	31.1	1.73	0.26	25.	11.6	9.5	0.78	0.08	7.6	4.3	4.1	0.30	0.05	7.9
1408	5.1	8.	17.8	1.72	0.28	14.	8.6	19.1	1.84	0.32	15.0	6.5	8.9	0.76	0.13	11.7
1423	7.4	38.	22.7	1.72	0.23	19.	60.1	35.9	2.72	0.36	30.0	21.5	17.9	1.44	0.22	19.2
1438	6.5	30	12.7	1.80	0.26	25.	43.5	18.4	2.60	0.36	36.3	32.4	22.5	2.09	0.31	28.3
1508	2.0	34	19.7	1.70	0.22	13.	24.7	—	1.24	0.16	9.4	44.7	—	2.71	0.39	33.
1538	0.3	34.	(19.7)	1.29	0.23	23.	2.5	7.9	0.10	0.02	1.7	45.9	30.4	2.76	0.40	34.
1608	0.2	34.	19.4	1.76	0.22	14.	1.6	—	0.08	0.01	0.7	47.5	—	2.84	0.41	35.
1753	0.1	19.	(19.4)	1.95	0.26	17.	0.8	0.9	0.08	0.01	0.7	48.7	32.6	2.97	0.43	36.

NOTES : CONCENTRATION VALUES IN PARENTHESES ARE ESTIMATED.

WOODHOLLOW DAM

EVENT 13 5/2/81



DATE : 9/14/81

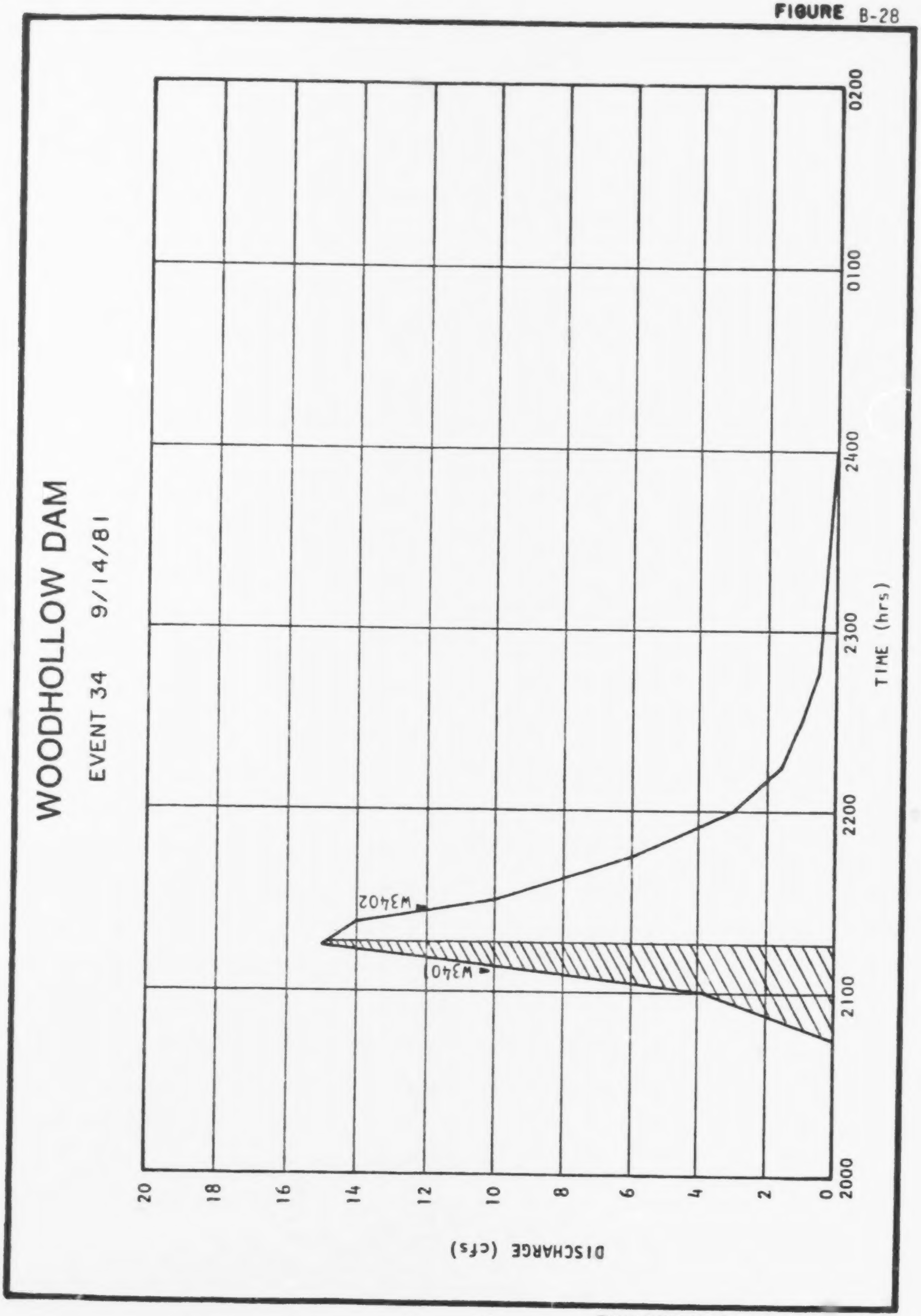
SITE : WOODHOLLOW DAM (DAM CLOSED)

TABLE B-28

EVENT NO. : 34

TIME	INST DIS (cfs)	INST POLL CONC (mg/l)					AVG MASS FLUX (lb/hr)					CUM MASS DISCHARGED (lbs)				
		COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS
2108	9.0	—	5.2	2.83	0.19	52.	—	4.9	2.61	0.17	49.	—	2.8	1.50	0.10	28.
2127	11.7	—	8.7	2.06	0.21	56.	—	13.3	3.15	0.32	86.	—	8.8	2.92	0.25	67.
2300	0.3	—	(6.0)	(2.00)	(0.15)	(20.)	—	0.9	0.29	0.02	2.9	—	10.7	3.56	0.30	73.

NOTES : ALL VALUES REPORTED AS NH_3-N ARE ACTUALLY TOTAL N. VALUES FOR CONCENTRATIONS IN PARENTHESES ARE ESTIMATED



WOODHOLLOW DAM

EVENT 34 9/14/81

DATE : 9/15/81

SITE : WOODHOLLOW DAM (DAM CLOSED)

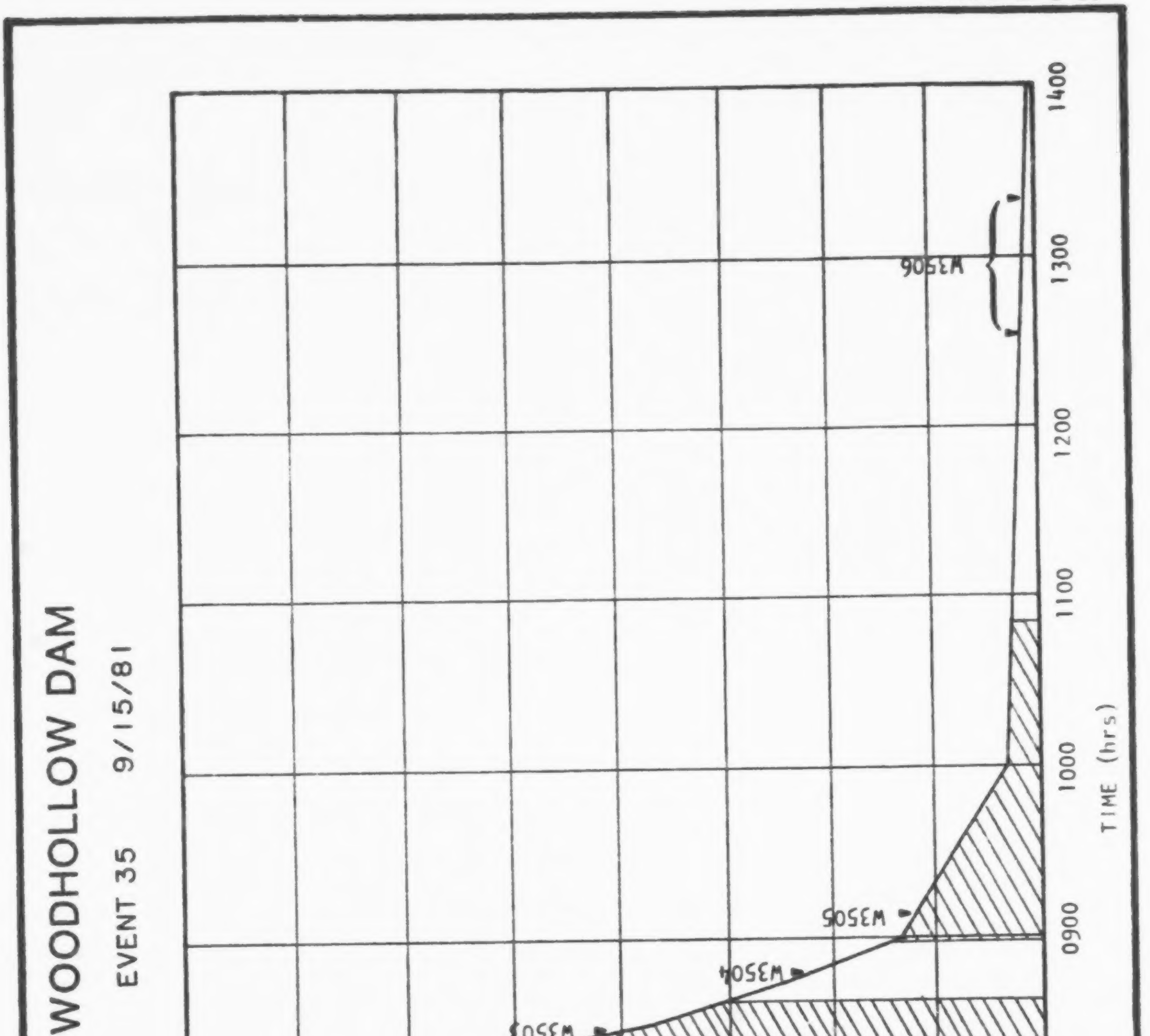
EVENT NO. : 35

TABLE B-29

TIME	INST DIS (cfs)	INST POLL CONC (mg/l)					AVG. MASS FLUX (lb/hr)					CUM MASS DISCHARGED (lbs)				
		COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS	COD	TOC	NH_3-N	TOT P	TSS
0748	11.	—	9.4	2.37	0.22	77.	—	18.4	4.62	0.44	150.	—	9.2	2.31	0.22	75.
0808	65	—	11.6	2.48	0.16	71	—	153.7	32.87	2.13	940.	—	55.3	12.17	0.86	121
0830	42.	—	11.7	2.17	0.11	27	—	98.1	18.21	0.93	227	—	92.1	19.00	1.21	158.
0848	20.	—	10.8	1.72	0.08	10.	—	53.0	8.43	0.40	50.	—	108.0	21.53	1.33	174
0908	12.	—	15.9	1.65	0.11	24	—	17.6	1.83	0.12	27	—	144.6	25.33	1.58	211.
1318	3.	—	8.7	2.21	0.16	20.	—	4.0	1.02	0.07	9.1	—	155.6	28.14	1.78	236.

NOTES : ALL NH_3-N VALUES ARE ACTUALLY TOTAL N VALUES

283



WOODHOLLOW DAM

EVENT 35 9/15/81

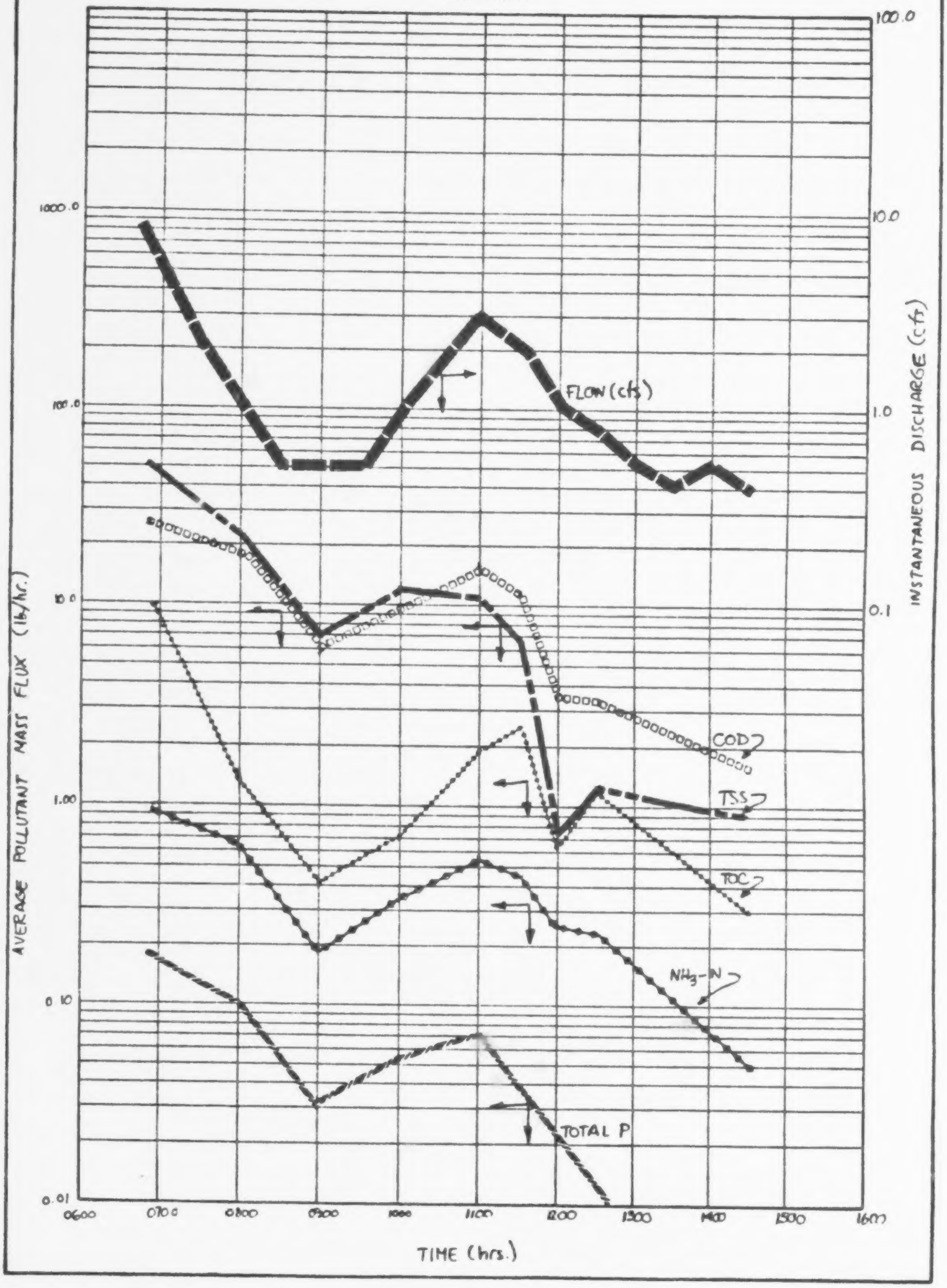
APPENDIX C

MASS LOADS AND CUMULATIVE MASS DISCHARGED FOR AUSTIN NURP STUDY NORTHWEST AUSTIN (HART LANE), ROLLINGWOOD, AND WOODHOLLOW DAM SITES

Figure C-1

ES ENGINEERING-SCIENCE

MASS FLUX
HART LANE SITE
EVENT 05
3/7/81



ES ENGINEERING - SCIENCE

CUMULATIVE MASS DISCHARGED
HART LANE SITE
EVENT 05
3/7/81

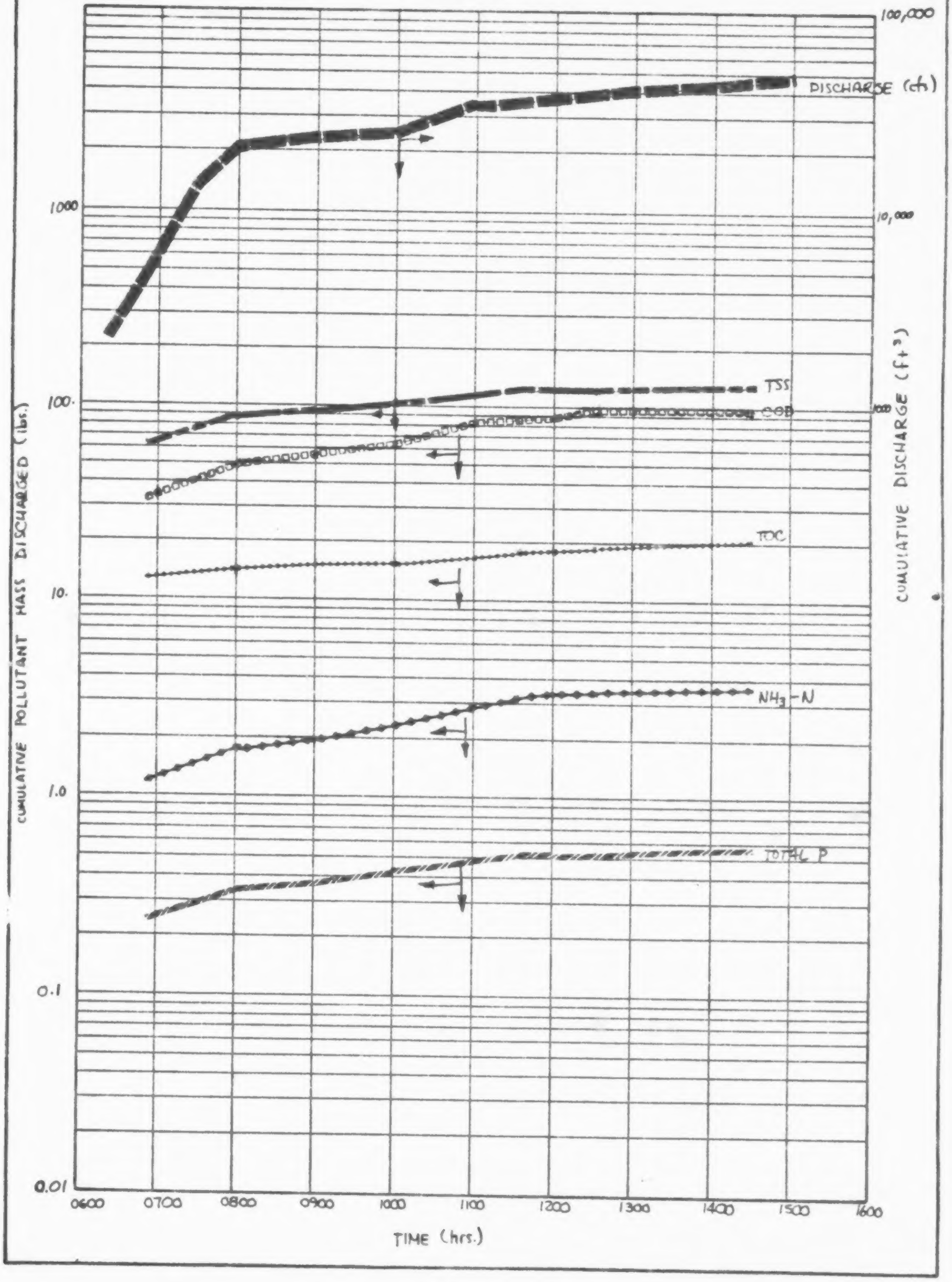
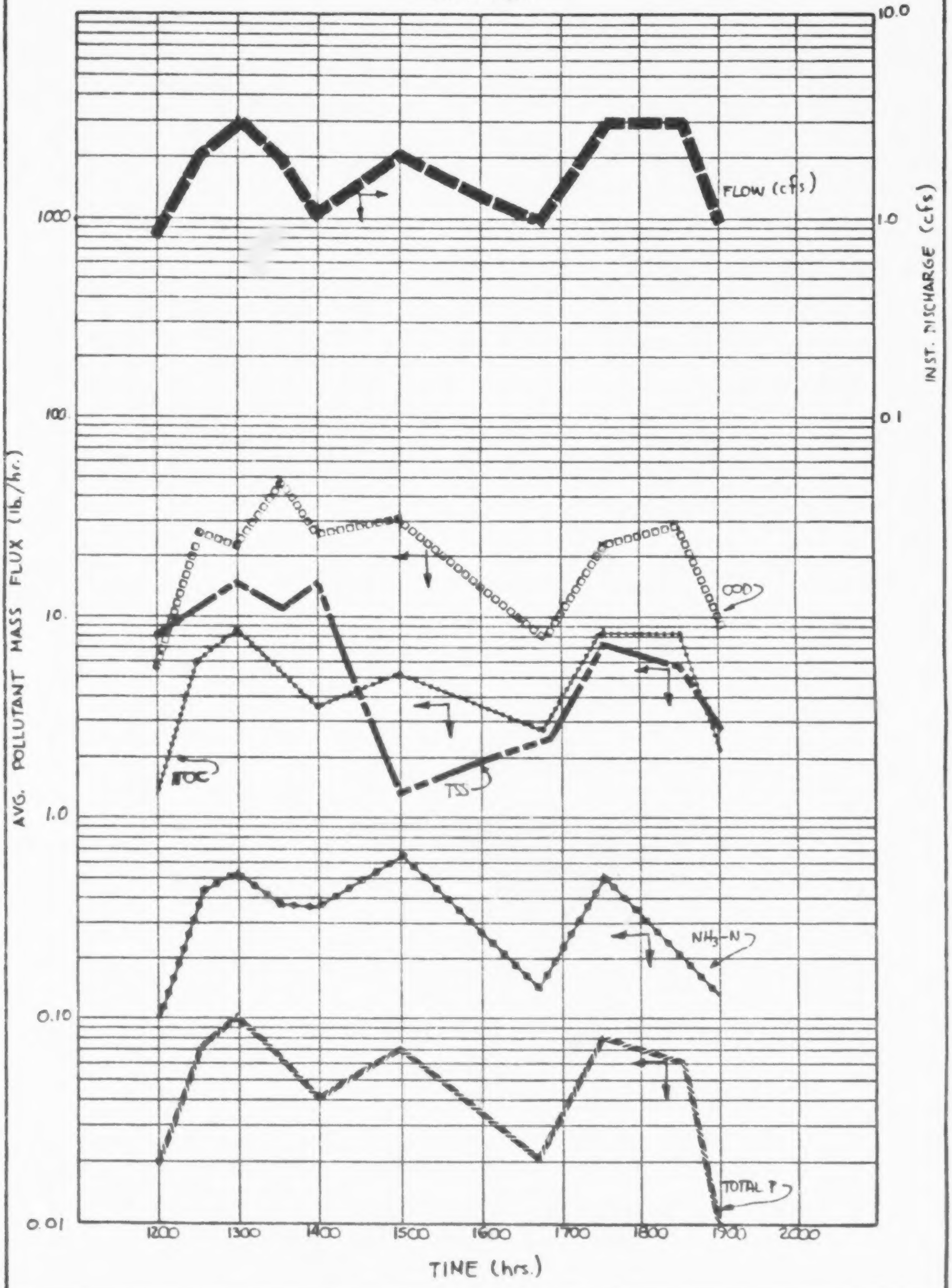


Figure C-3

ES ENGINEERING-SCIENCE

MASS FLUX
HART LANE SITE
EVENT 06
3/11/81



CUMULATIVE MASS DISCHARGED
HART LANE SITE
EVENT 06
3/11/81

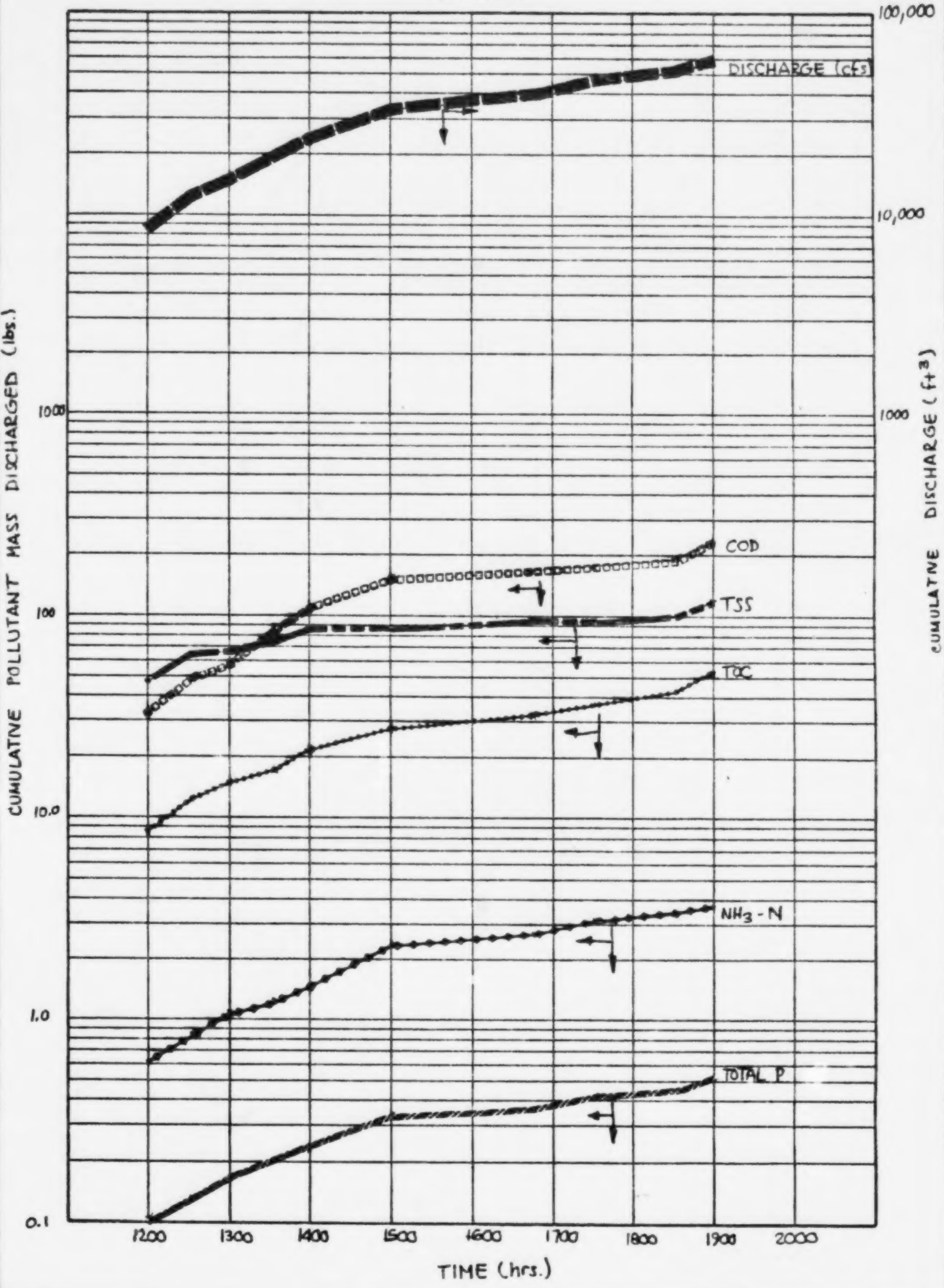
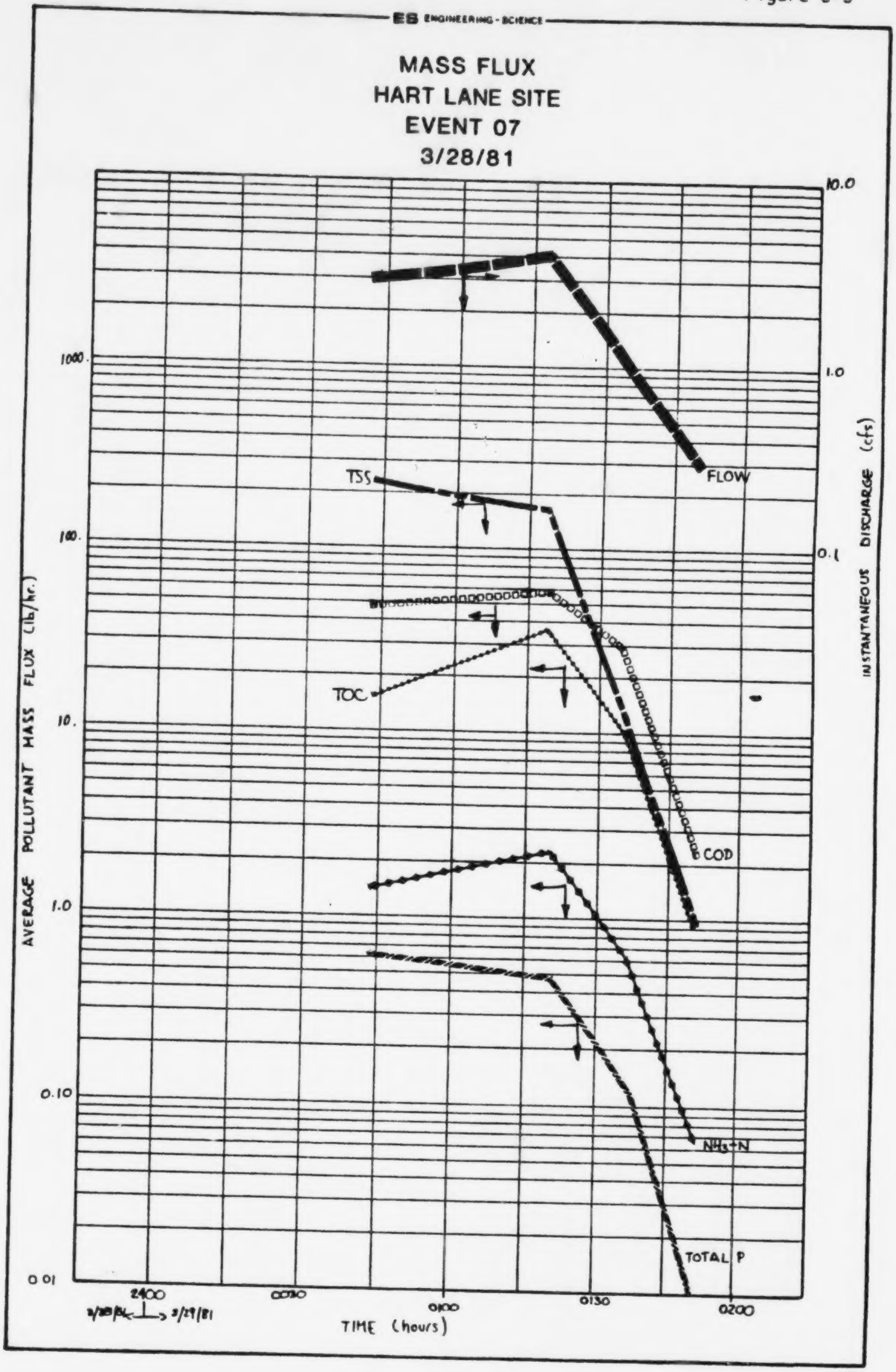


Figure C-5

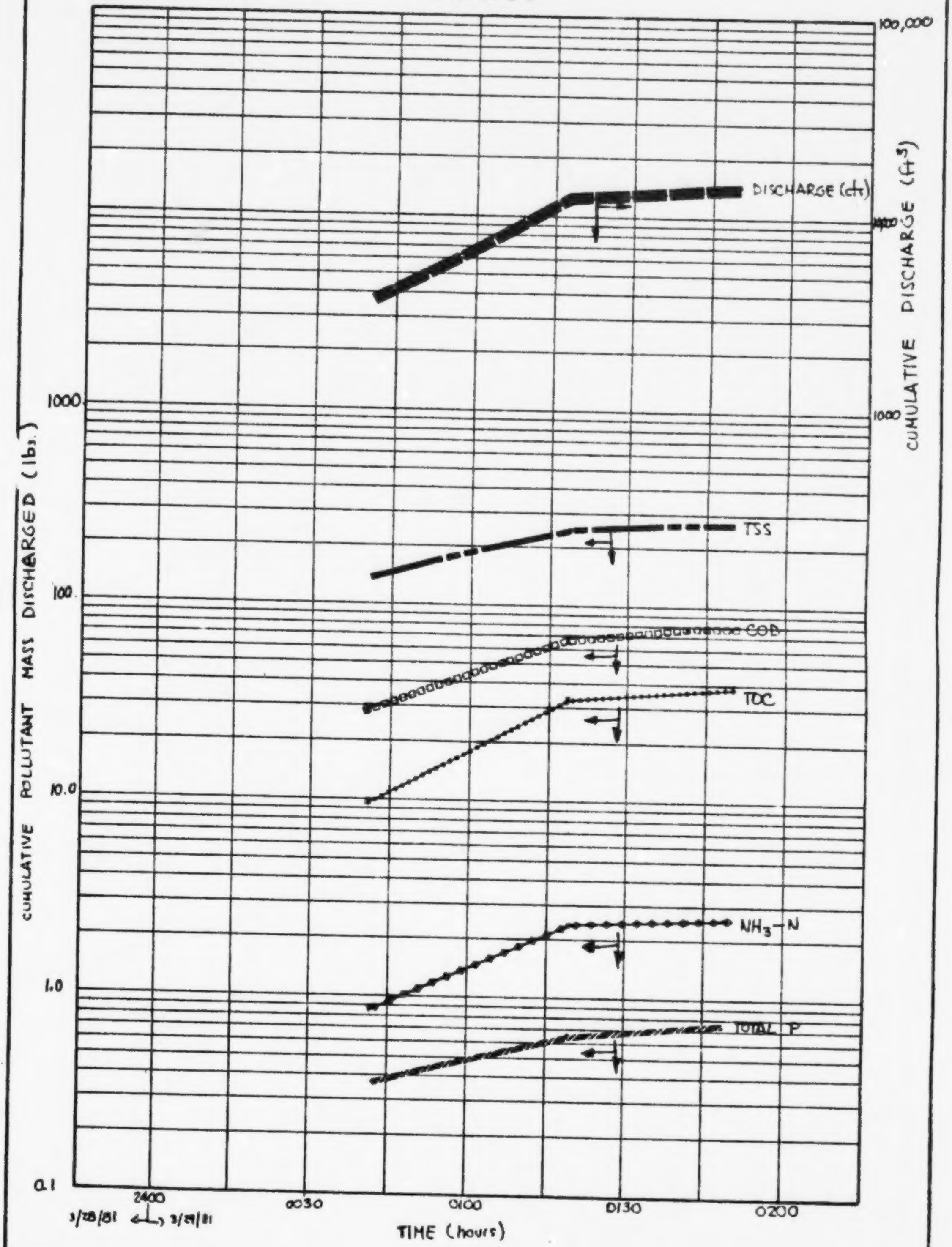


MASS FLUX
HART LANE SITE
EVENT 07
3/28/81

Figure C-6

ES ENGINEERING-SCIENCE

CUMULATIVE MASS DISCHARGED
HART LANE SITE
EVENT 07
3/28/81



MASS FLUX
HART LANE SITE
EVENT 08
4/17/81

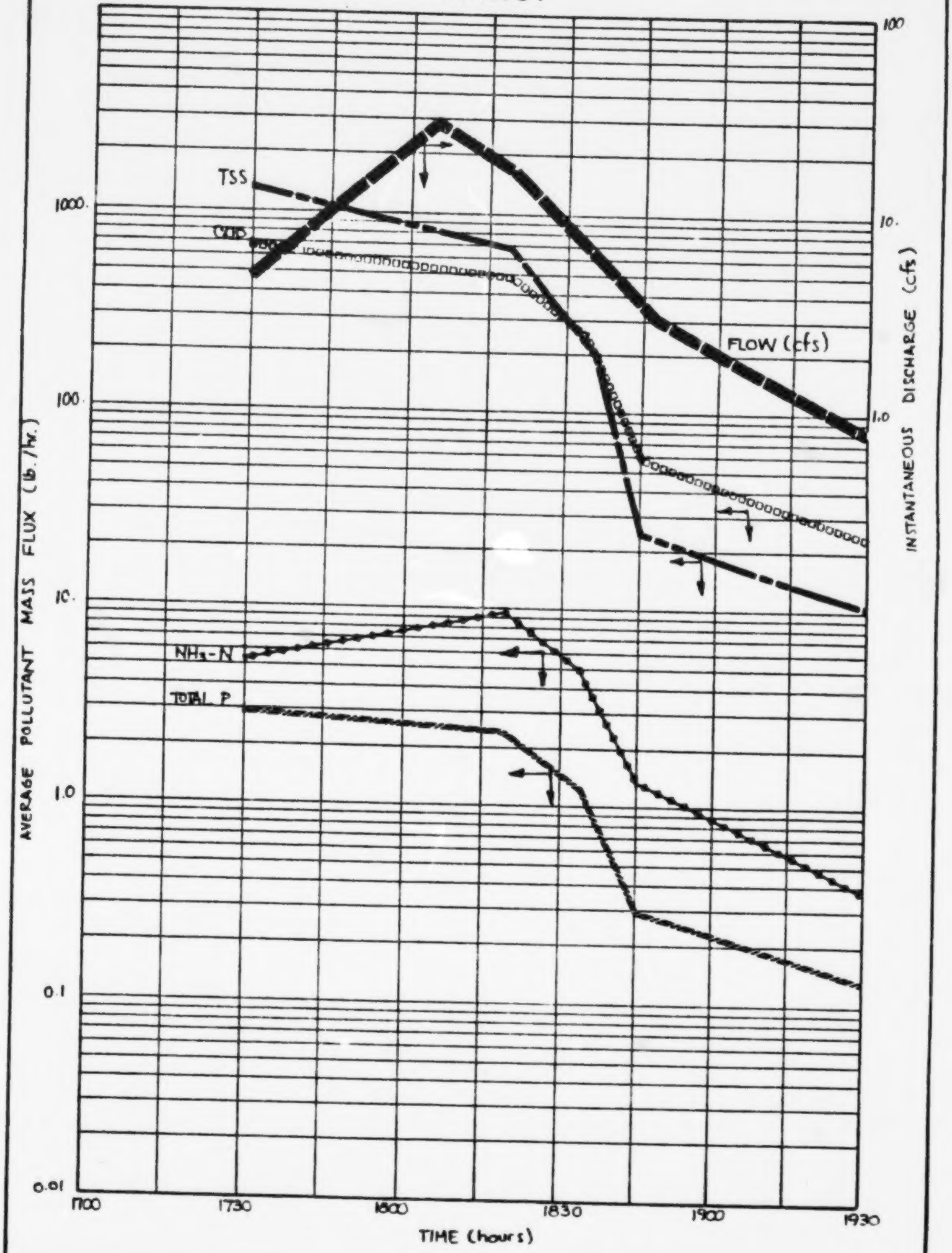


Figure C-8

ES ENGINEERING - SCIENCE

CUMULATIVE MASS DISCHARGED
HART LANE SITE
EVENT 08
4/17/81

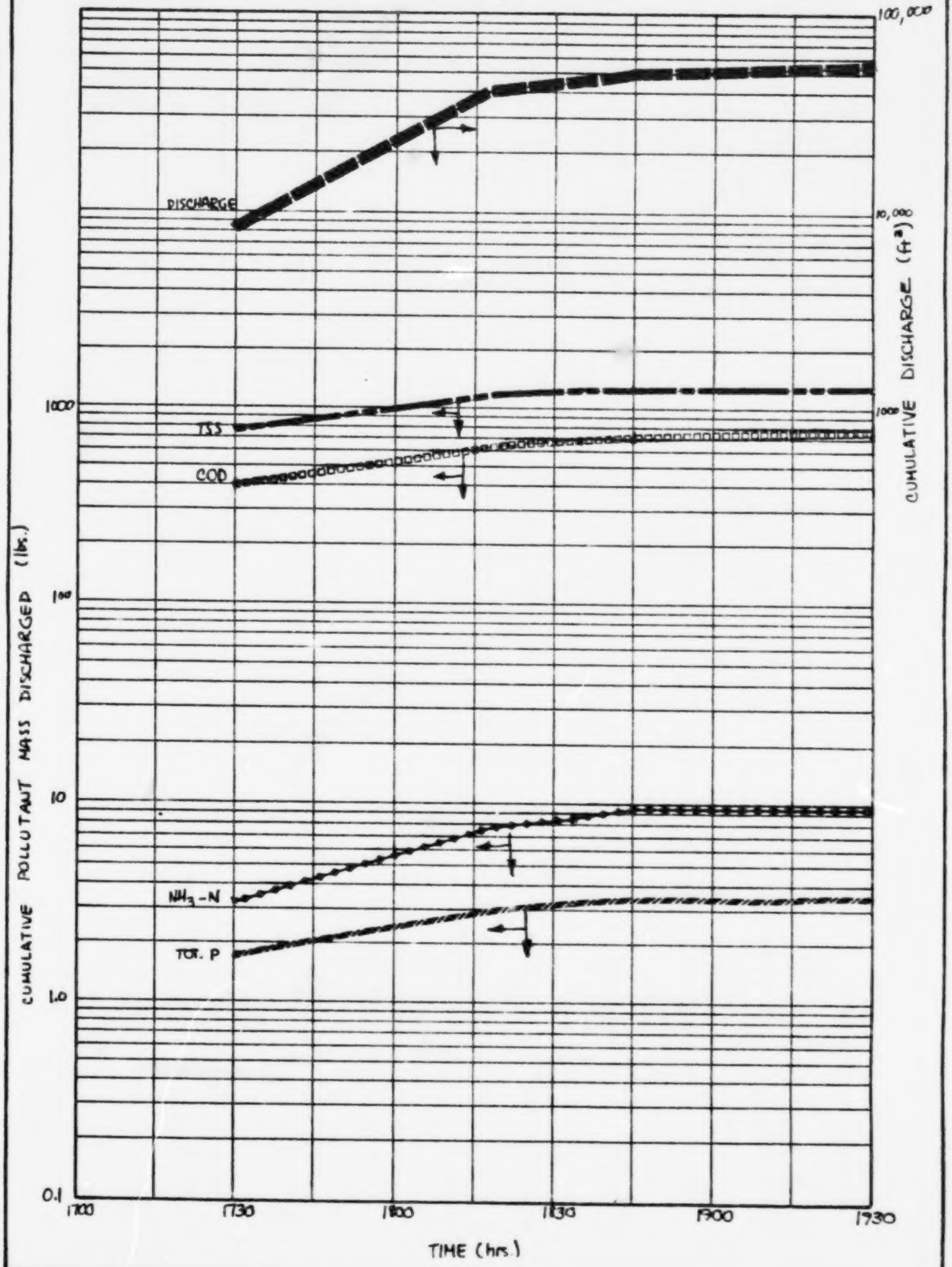


Figure C-9

ES ENGINEERING-SCIENCE

MASS FLUX
HART LANE SITE
EVENT 14
5/16/81

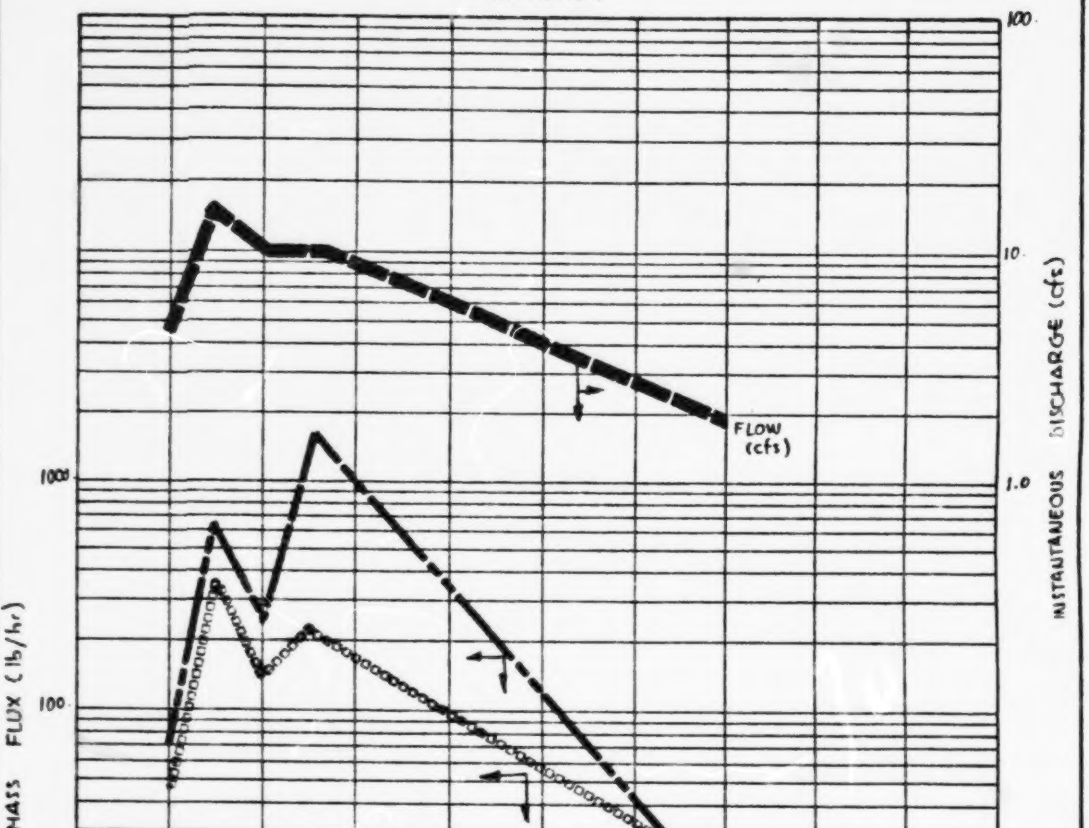
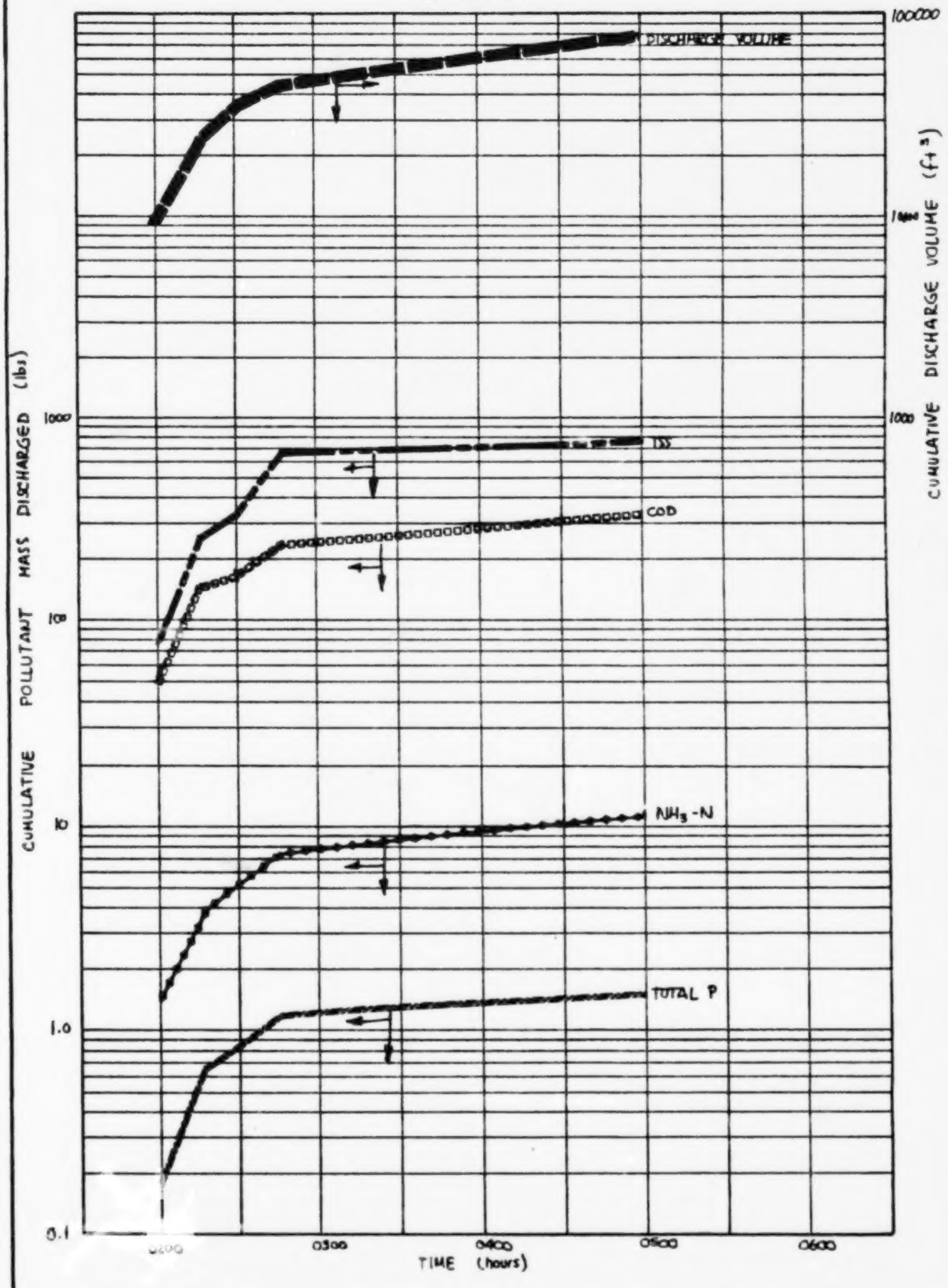


Figure C-10

ES ENGINEERING-SCIENCE

CUMULATIVE MASS DISCHARGED
HART LANE SITE
EVENT 14
5/16/81



ES ENGINEERING-SCIENCE

MASS FLUX
HART LANE SITE
EVENT 15
5/24/81

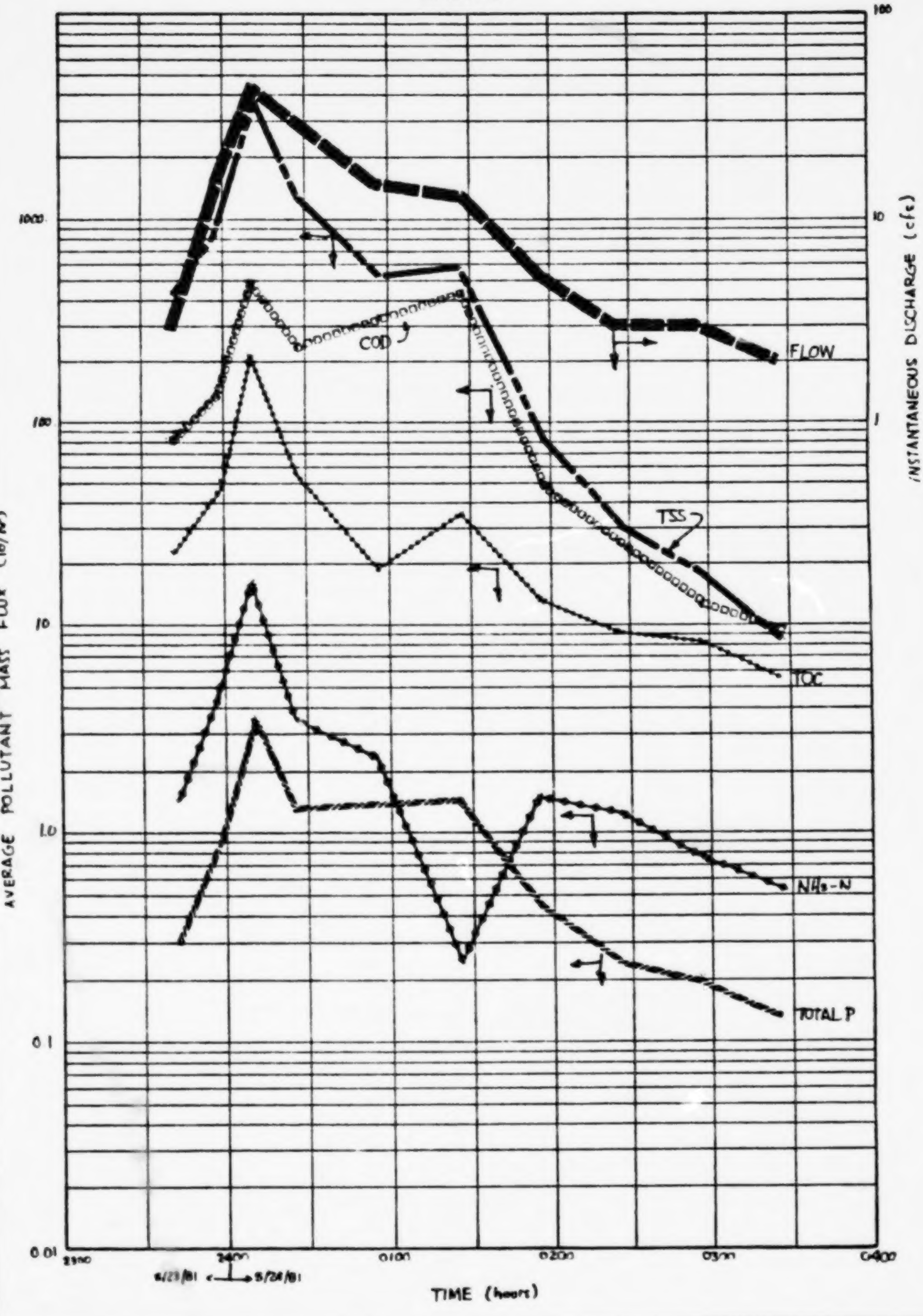


Figure C-12

CUMULATIVE MASS DISCHARGED
HART LANE SITE
EVENT 15
5/24/81

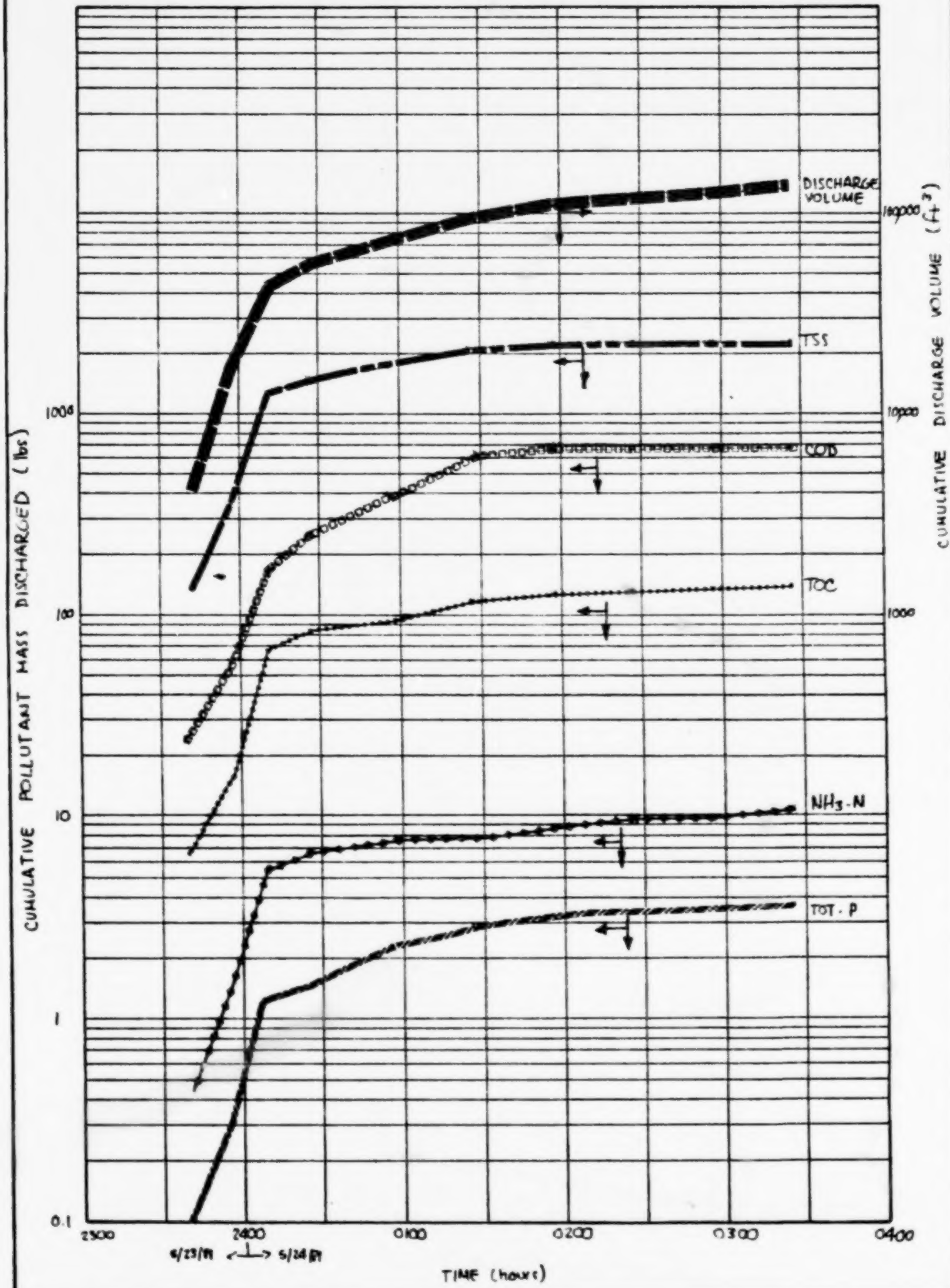


Figure C-13

ES ENGINEERING-SCIENCE

MASS FLUX
HART LANE SITE
EVENT 18
6/1/81

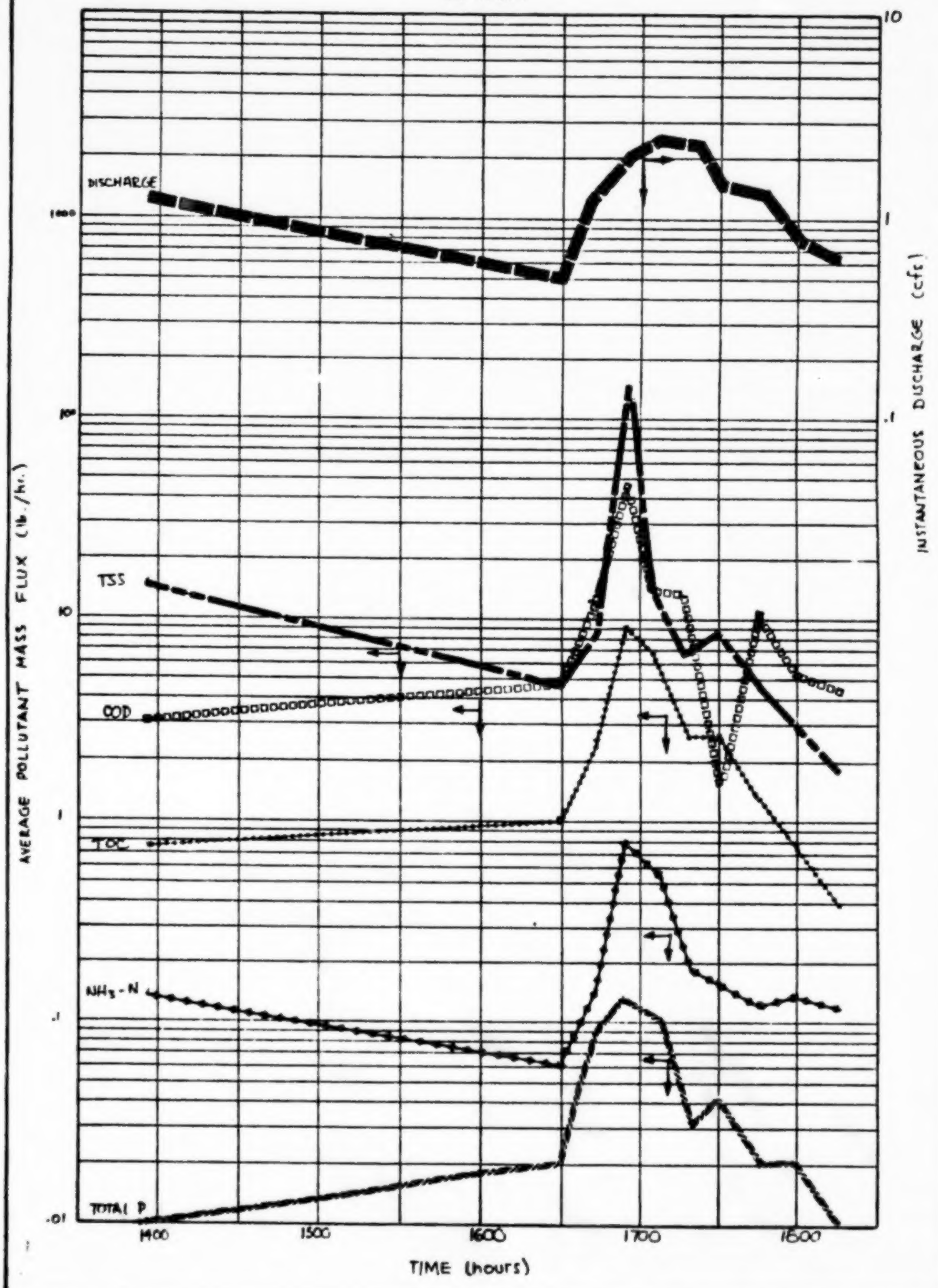


Figure C-14

ES ENGINEERING-SCIENCE

CUMULATIVE MASS DISCHARGED
HART LANE SITE
EVENT 18
6/1/81

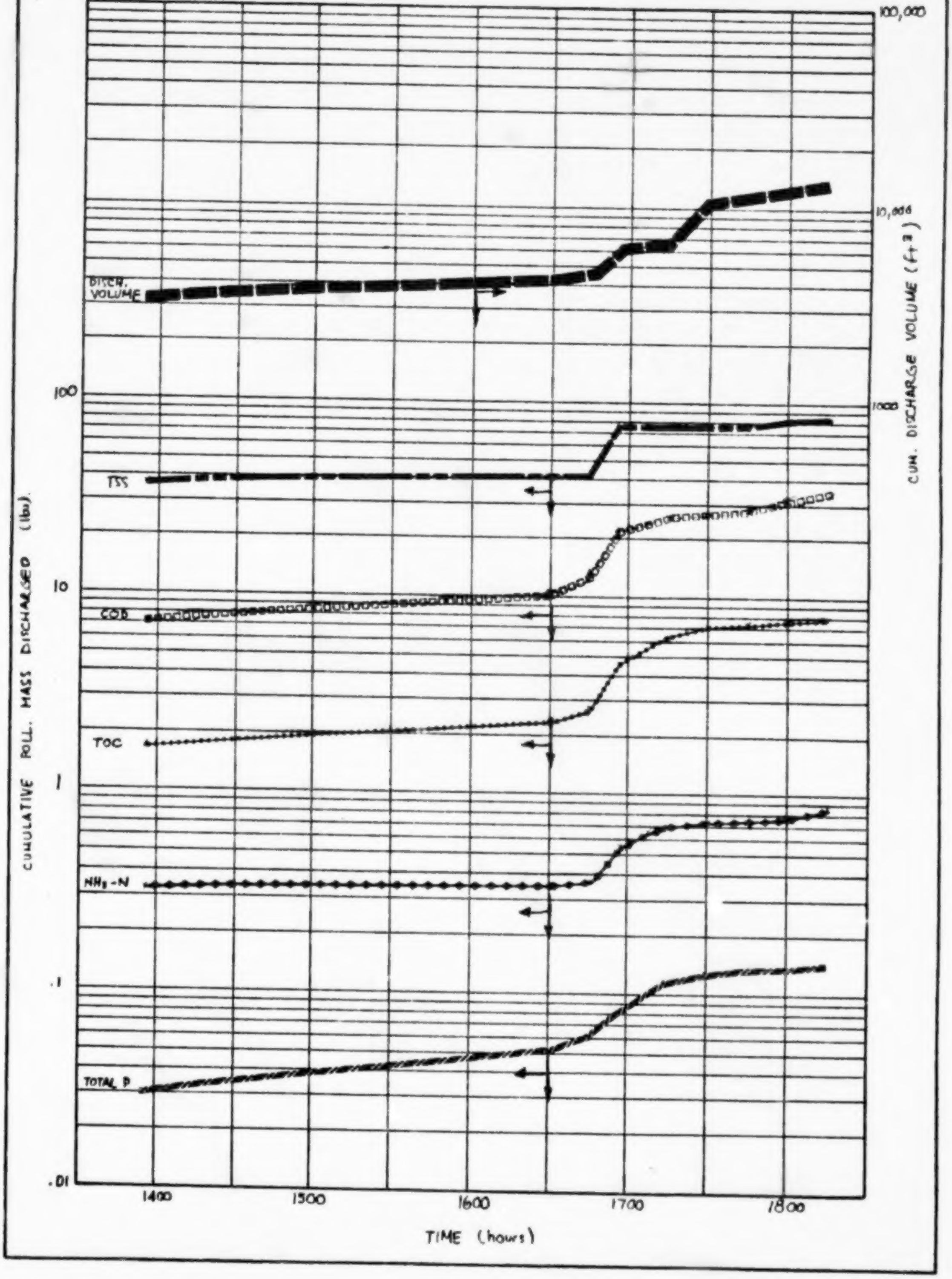


Figure C-15

ES ENGINEERING-SCIENCE

MASS FLUX
HART LANE SITE
EVENT 19
6/2/81

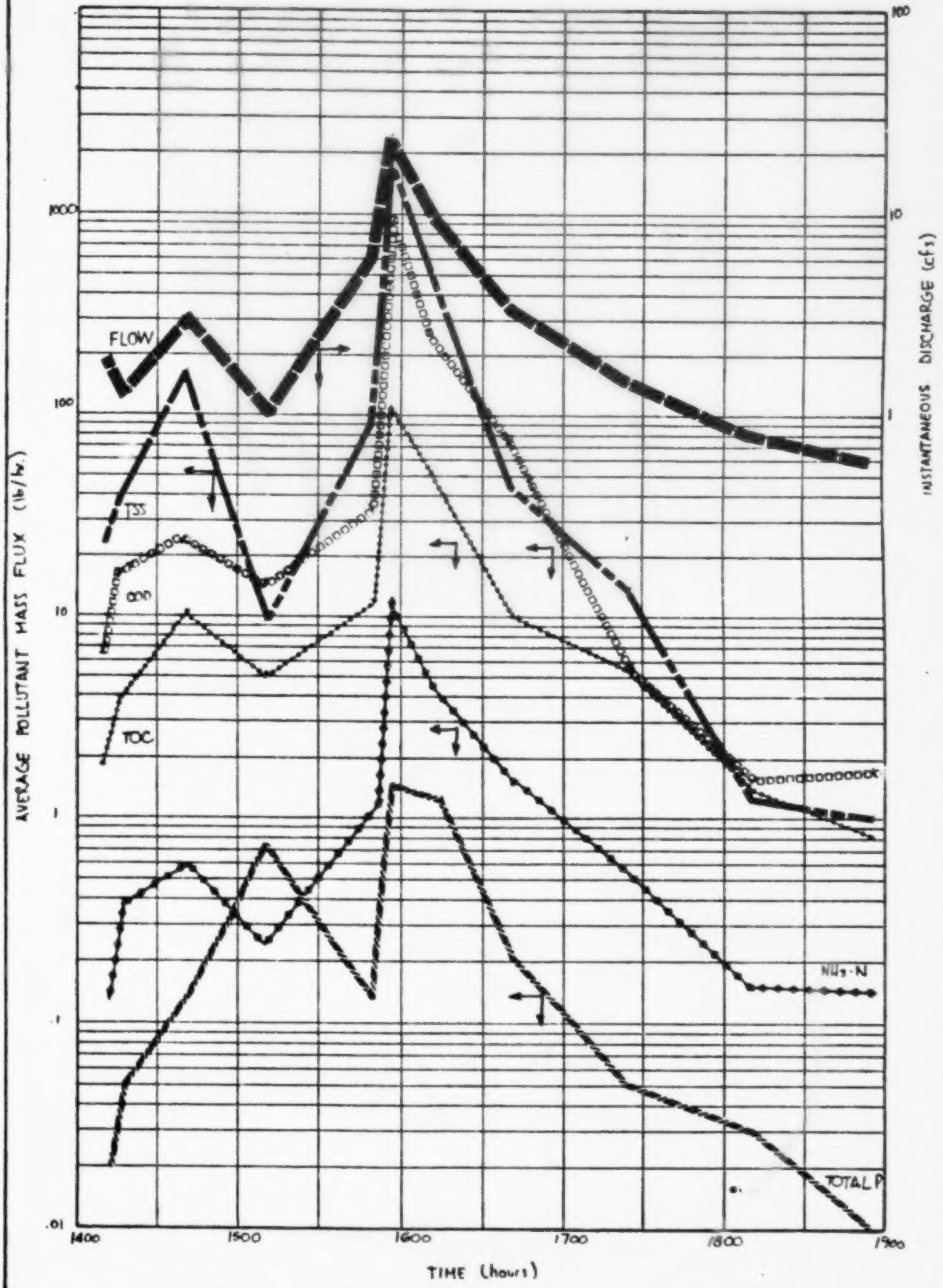
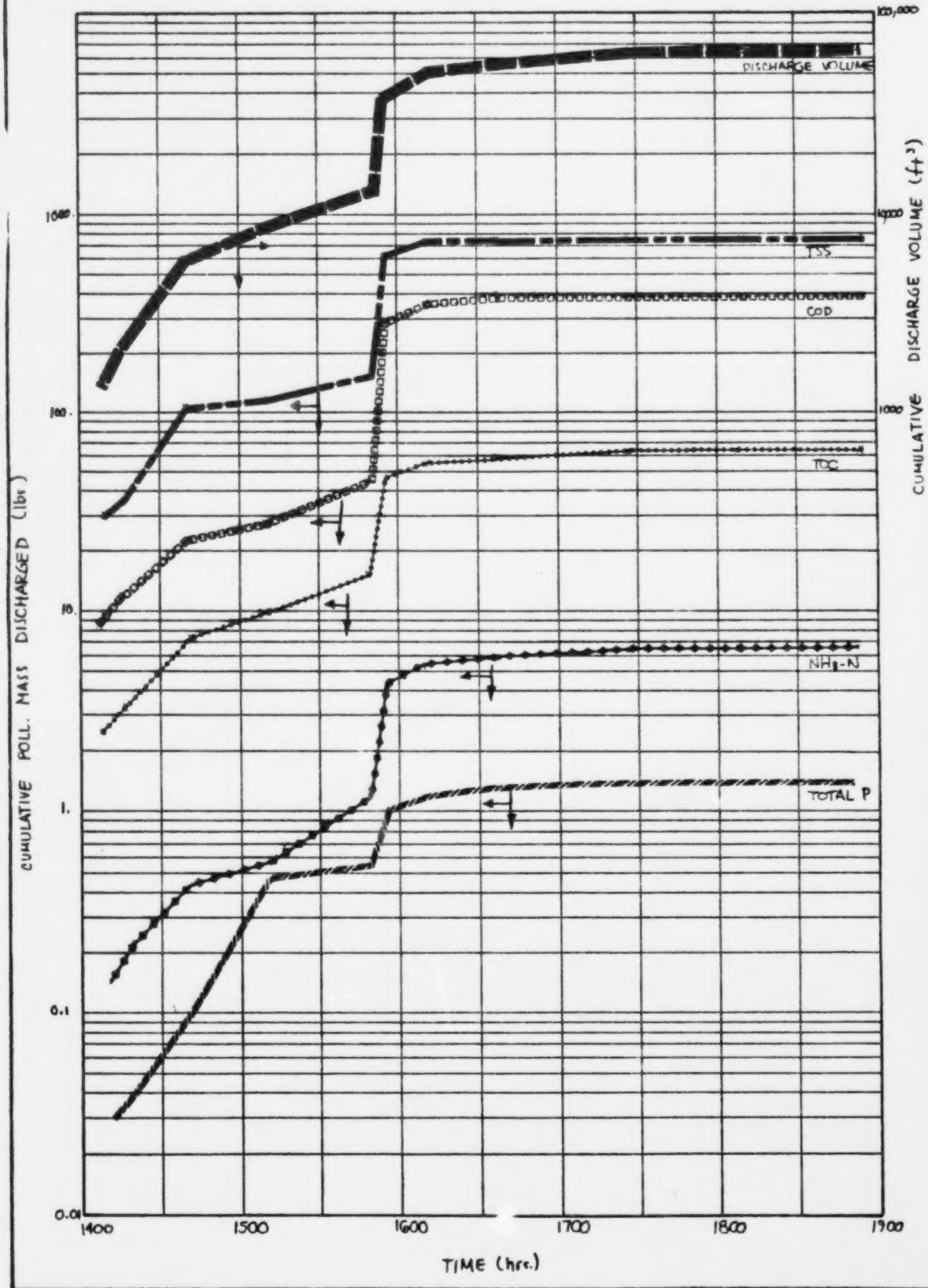


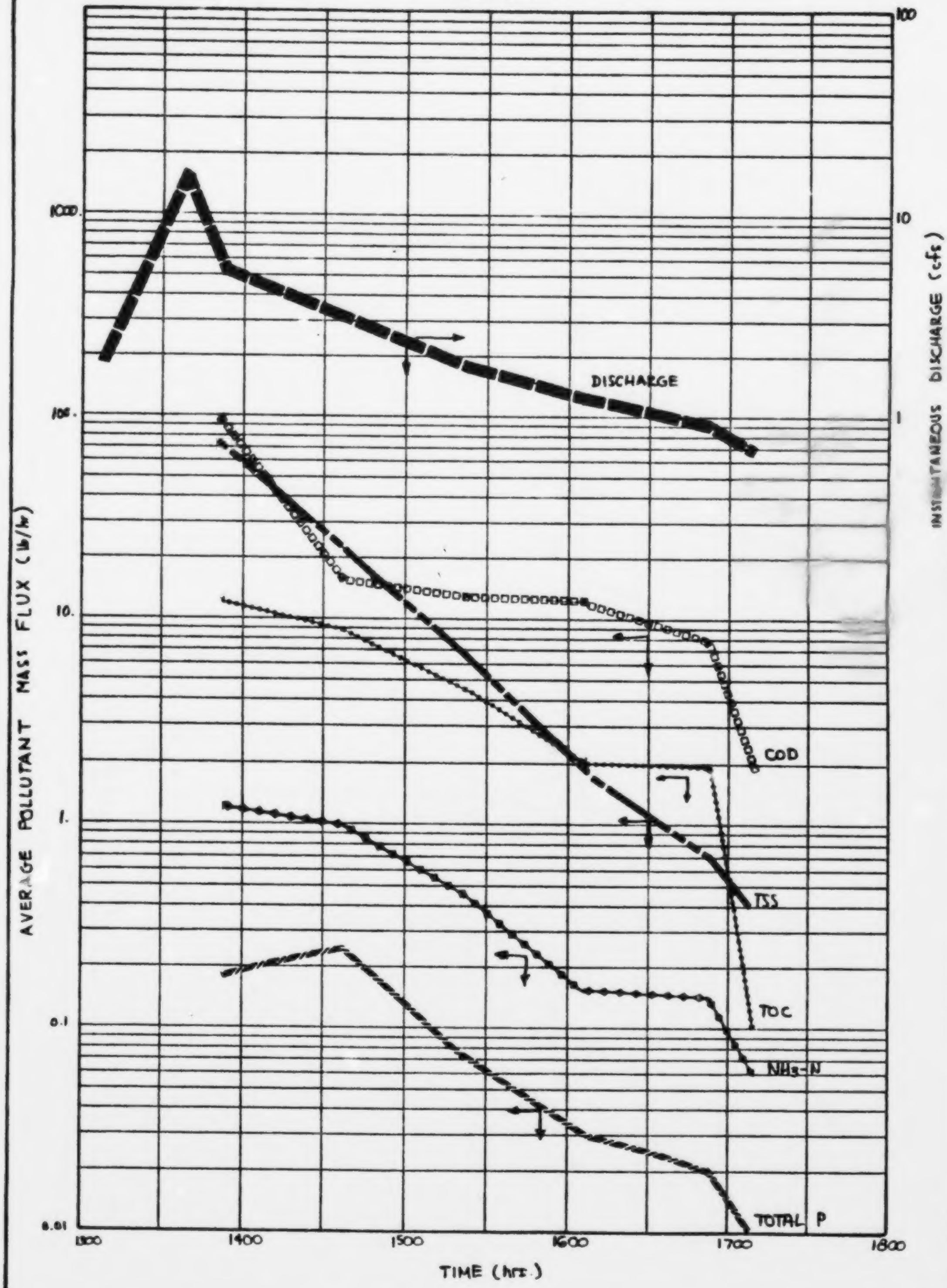
Figure C-16

ES ENGINEERING-SCIENCE

CUMULATIVE MASS DISCHARGED
HART LANE SITE
EVENT 19
6/2/81



MASS FLUX
HART LANE SITE
EVENT 20
6/3/81



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CUMULATIVE MASS DISCHARGED
HART LANE SITE
EVENT 20
6/3/81

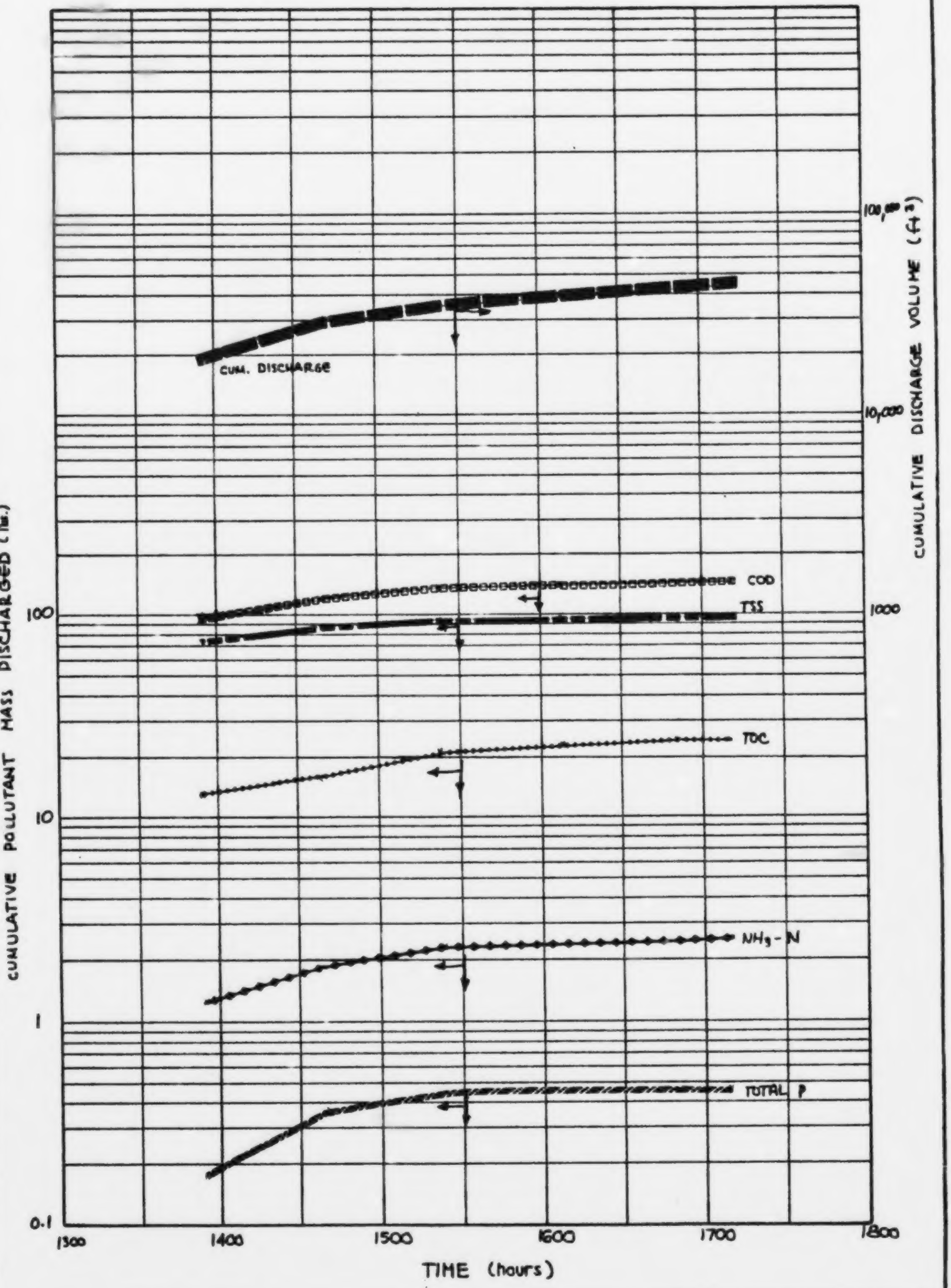


Figure C-19

ES ENGINEERING-SCIENCE

MASS FLUX
HART LANE SITE
EVENT 32
8/29/81

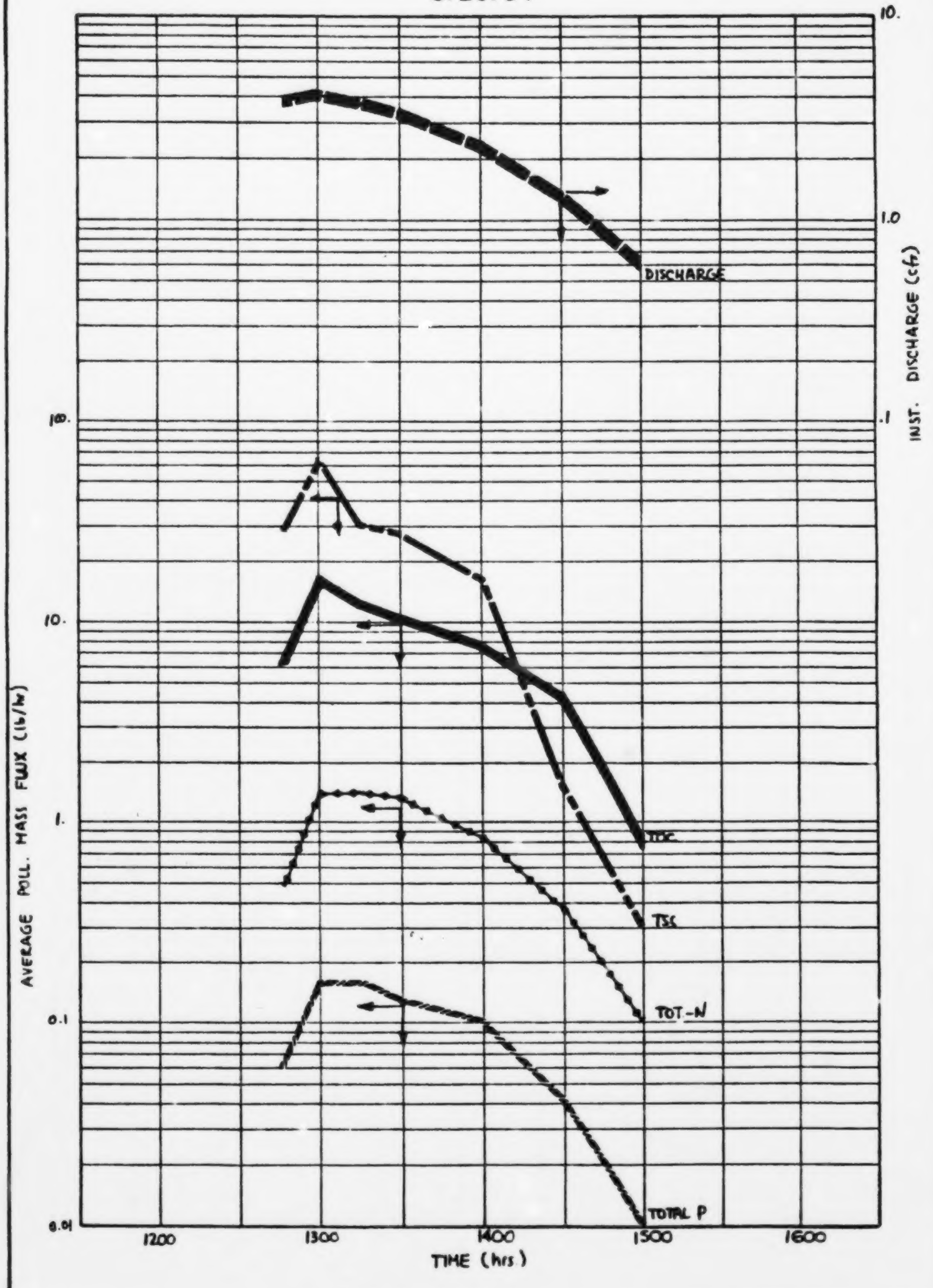


Figure C-20

ES ENGINEERING - SCIENCE

CUMULATIVE MASS DISCHARGED
HART LANE SITE
EVENT 32
8/29/81

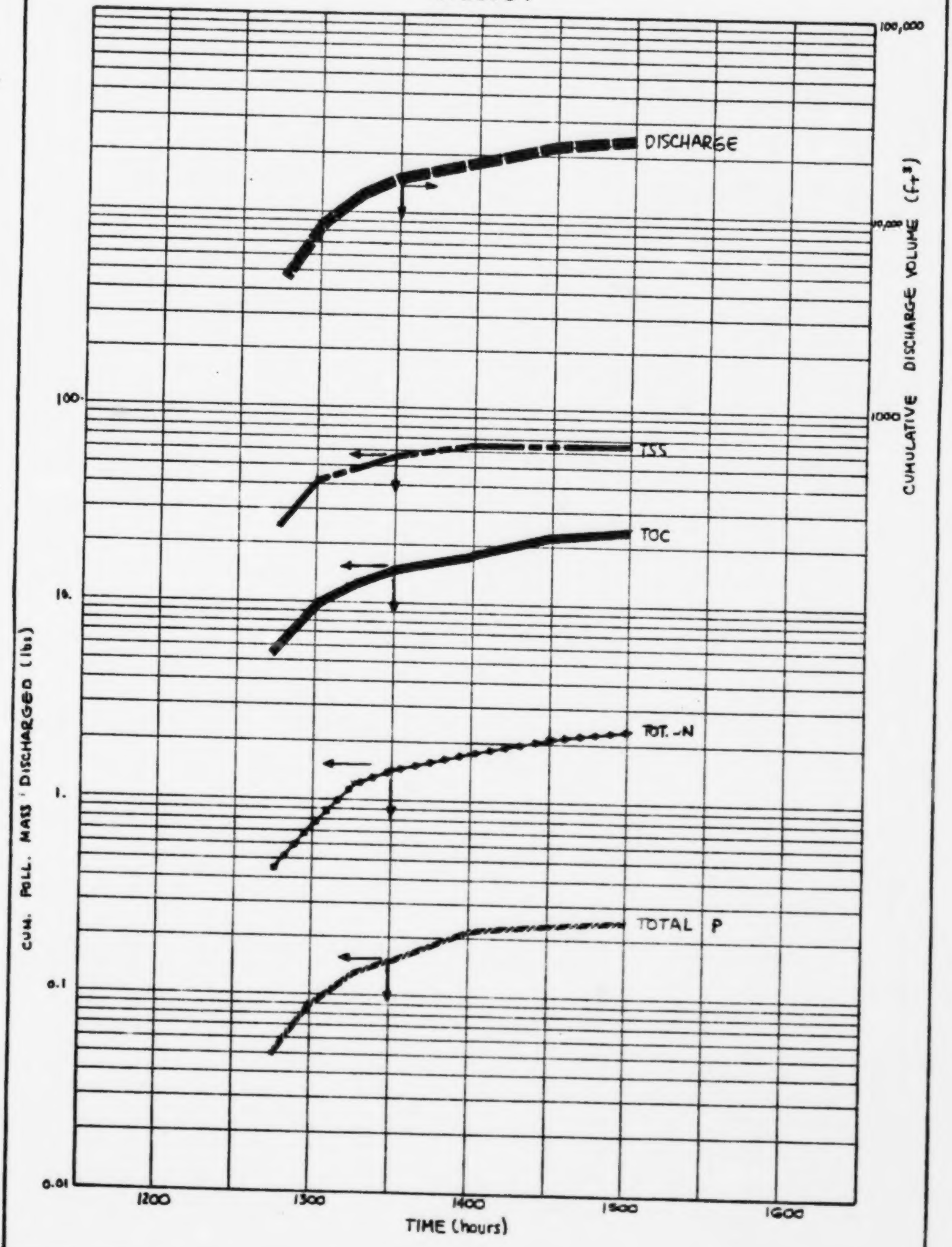


Figure C-21

ES ENGINEERING-SCIENCE

MASS FLUX
HART LANE SITE
EVENT 32.5
8/30/81

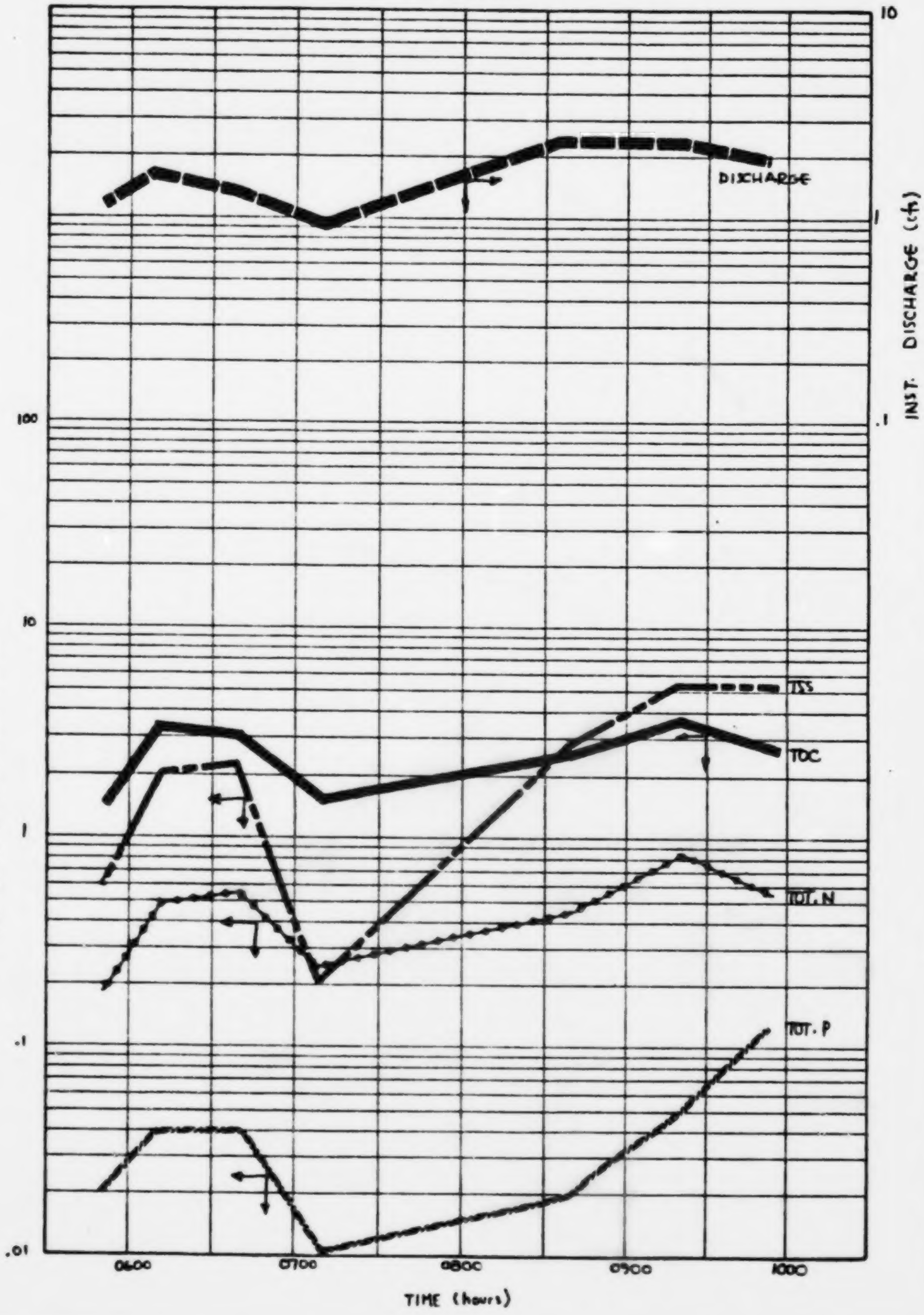
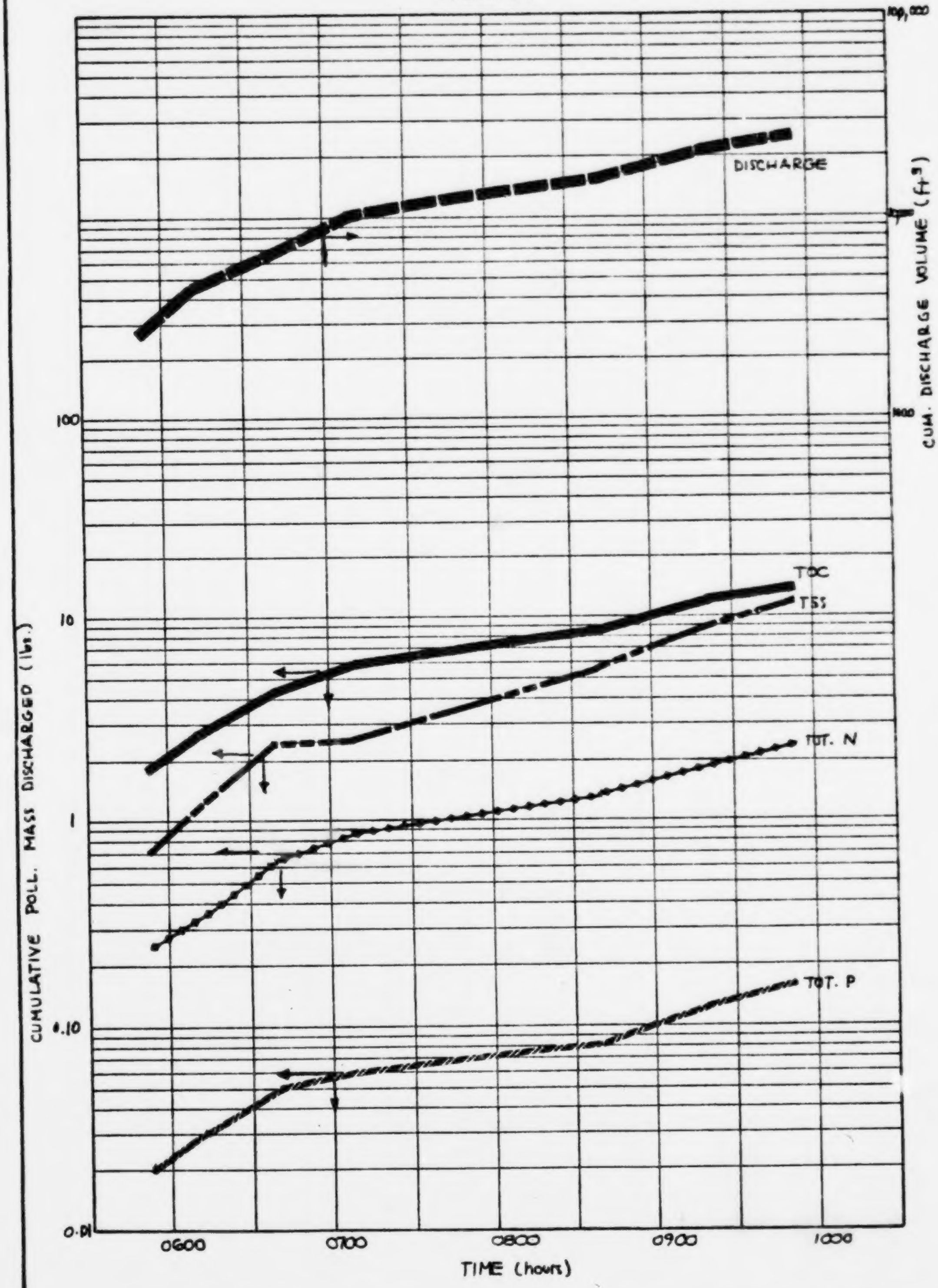


Figure C-22

ES ENGINEERING - SCIENCE

CUMULATIVE MASS DISCHARGED
HART LANE SITE
EVENT 32.5
8/29/81



MASS FLUX
HART LANE SITE
EVENT 34
9/14/81

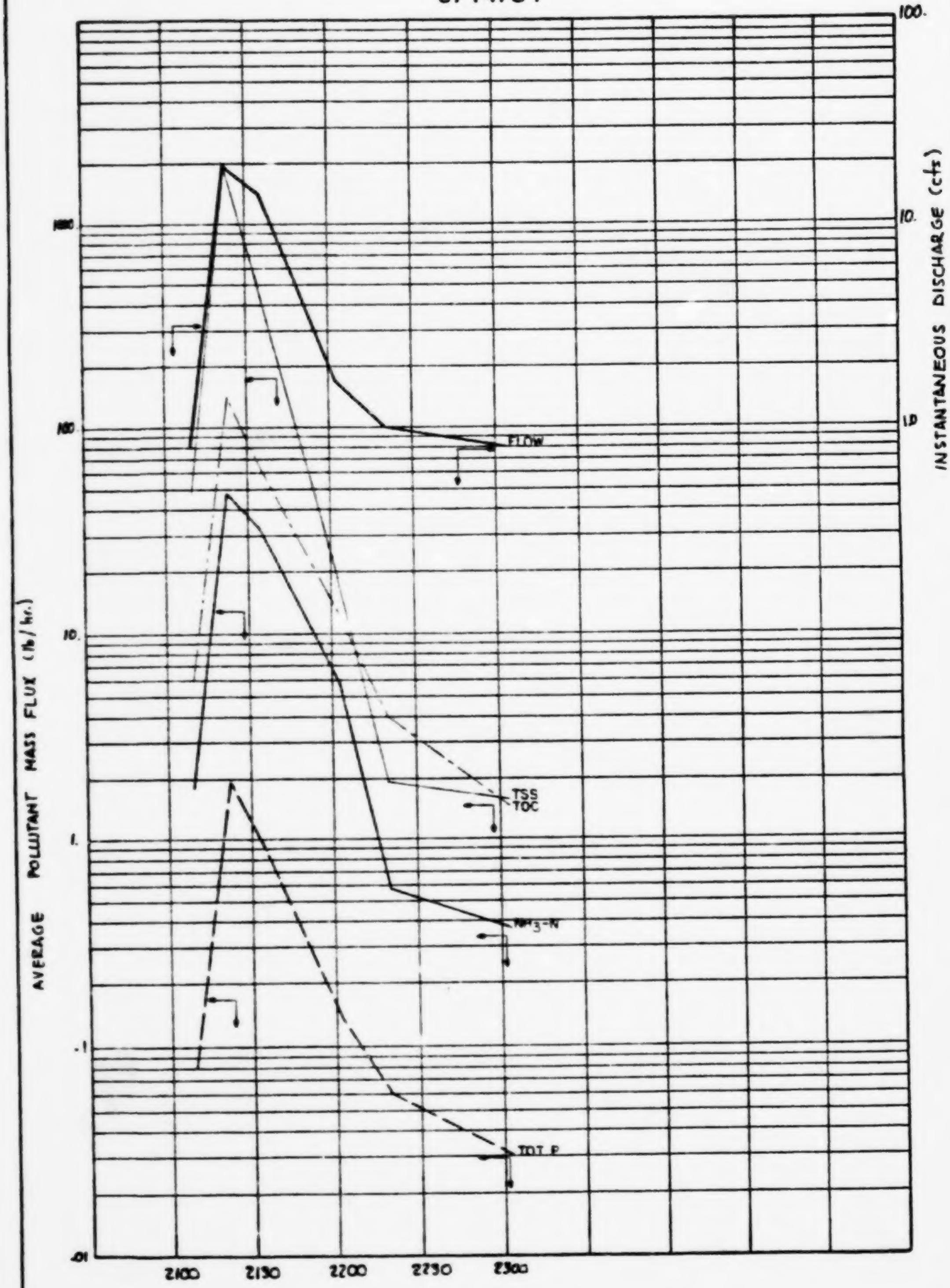


Figure C-24

ES ENGINEERING-SCIENCE

CUMULATIVE MASS DISCHARGED
HART LANE SITE
EVENT 34
9/14/81

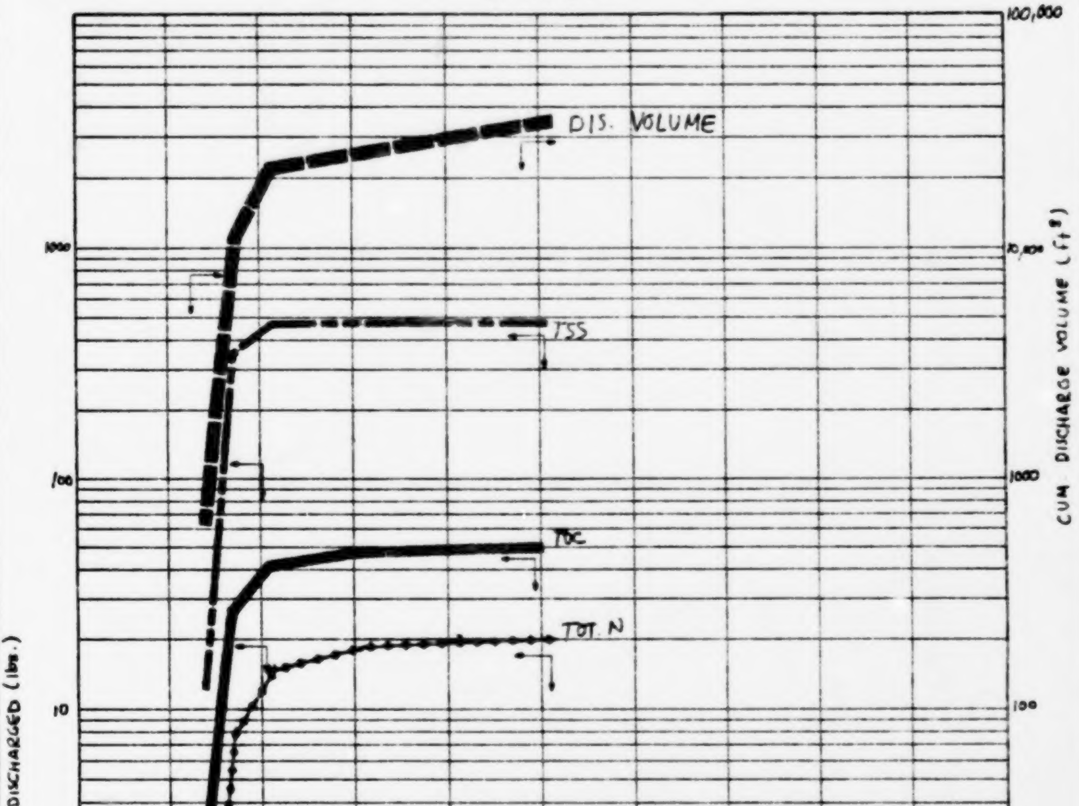


Figure C-25

ES ENGINEERING-SCIENCE

MASS FLUX
HART LANE SITE
EVENT 35
9/15/81

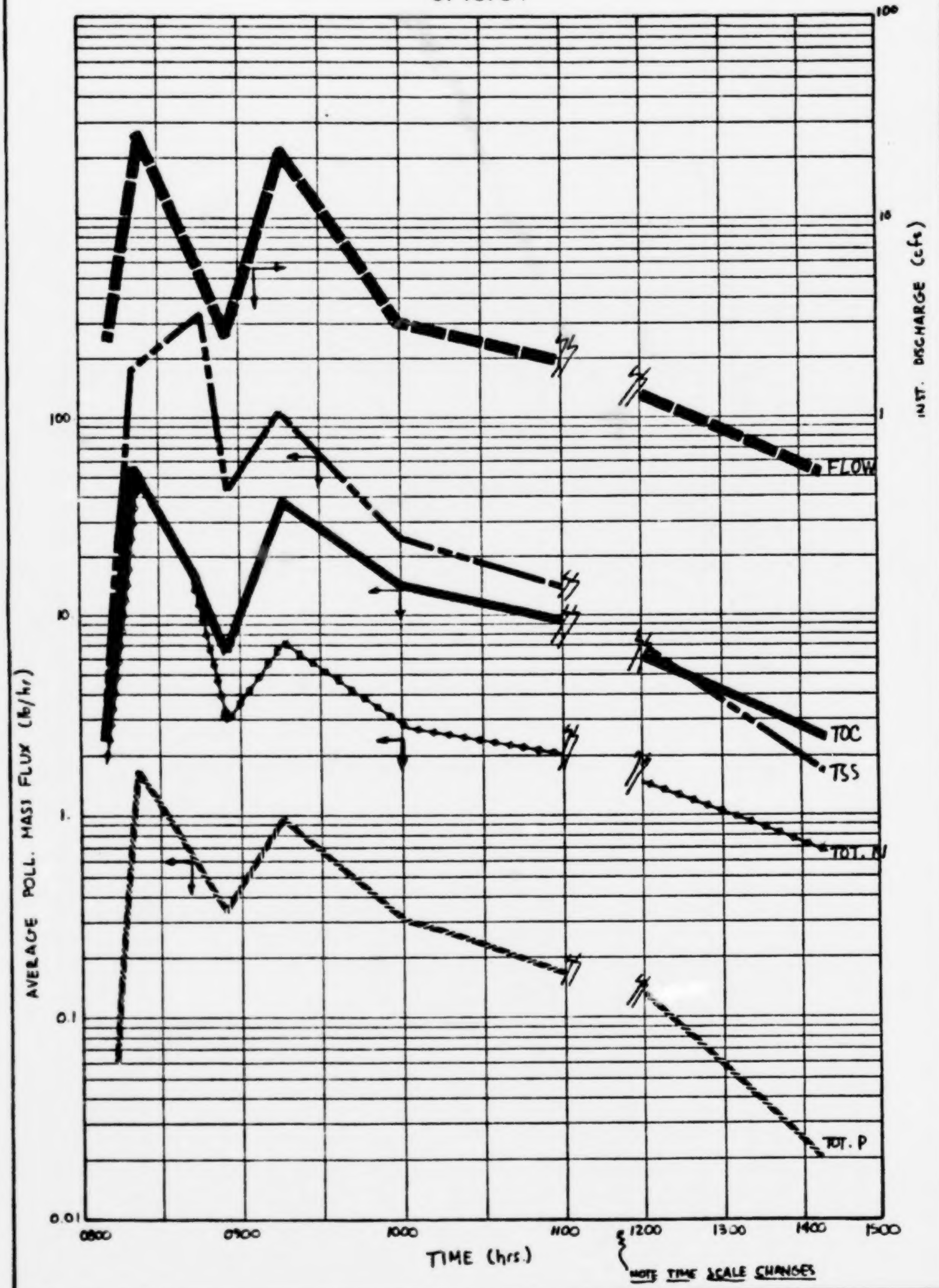


Figure C-26

ES ENGINEERING-SCIENCE

CUMULATIVE MASS DISCHARGED
HART LANE SITE
EVENT 35
9/15/81

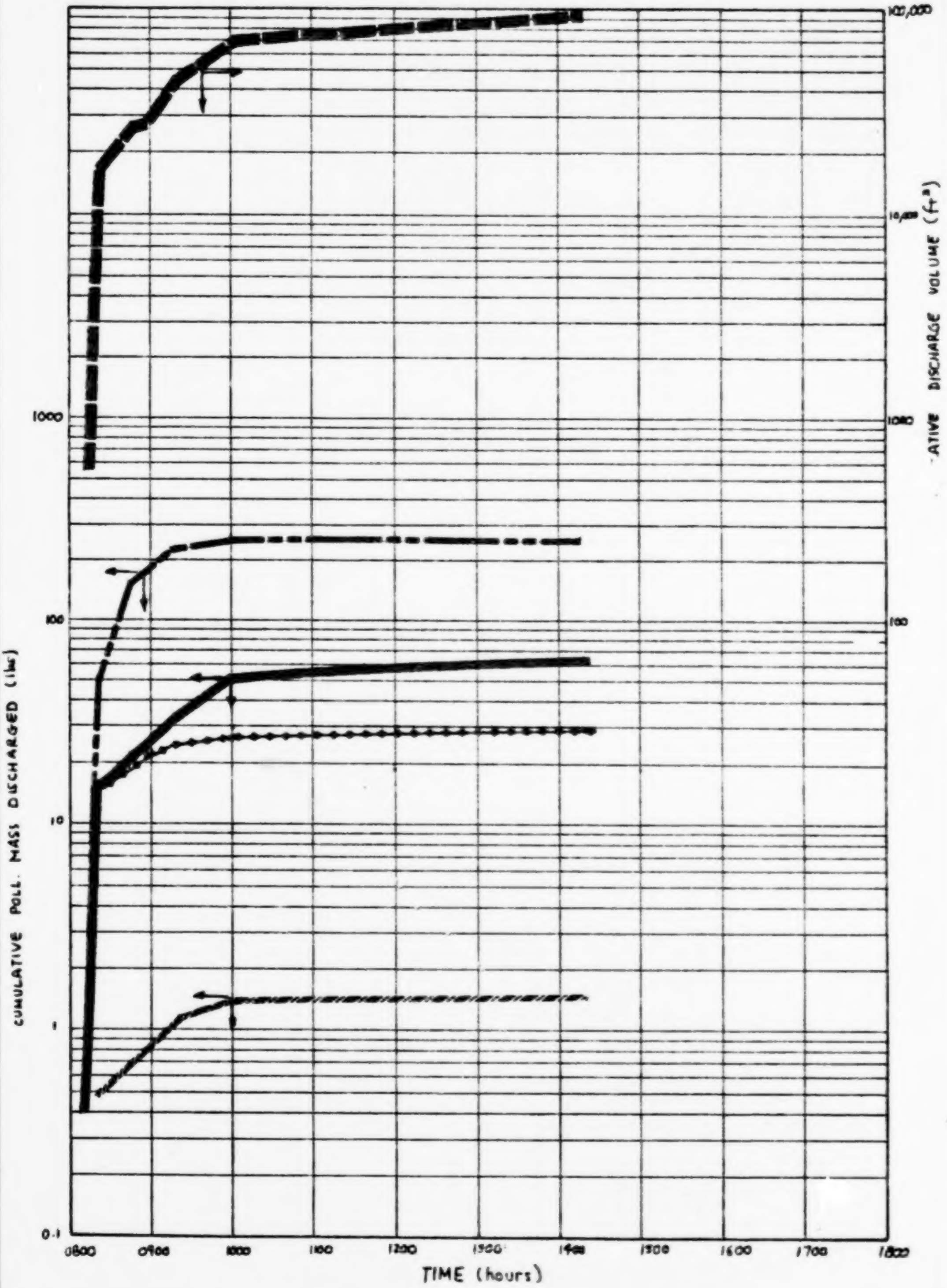


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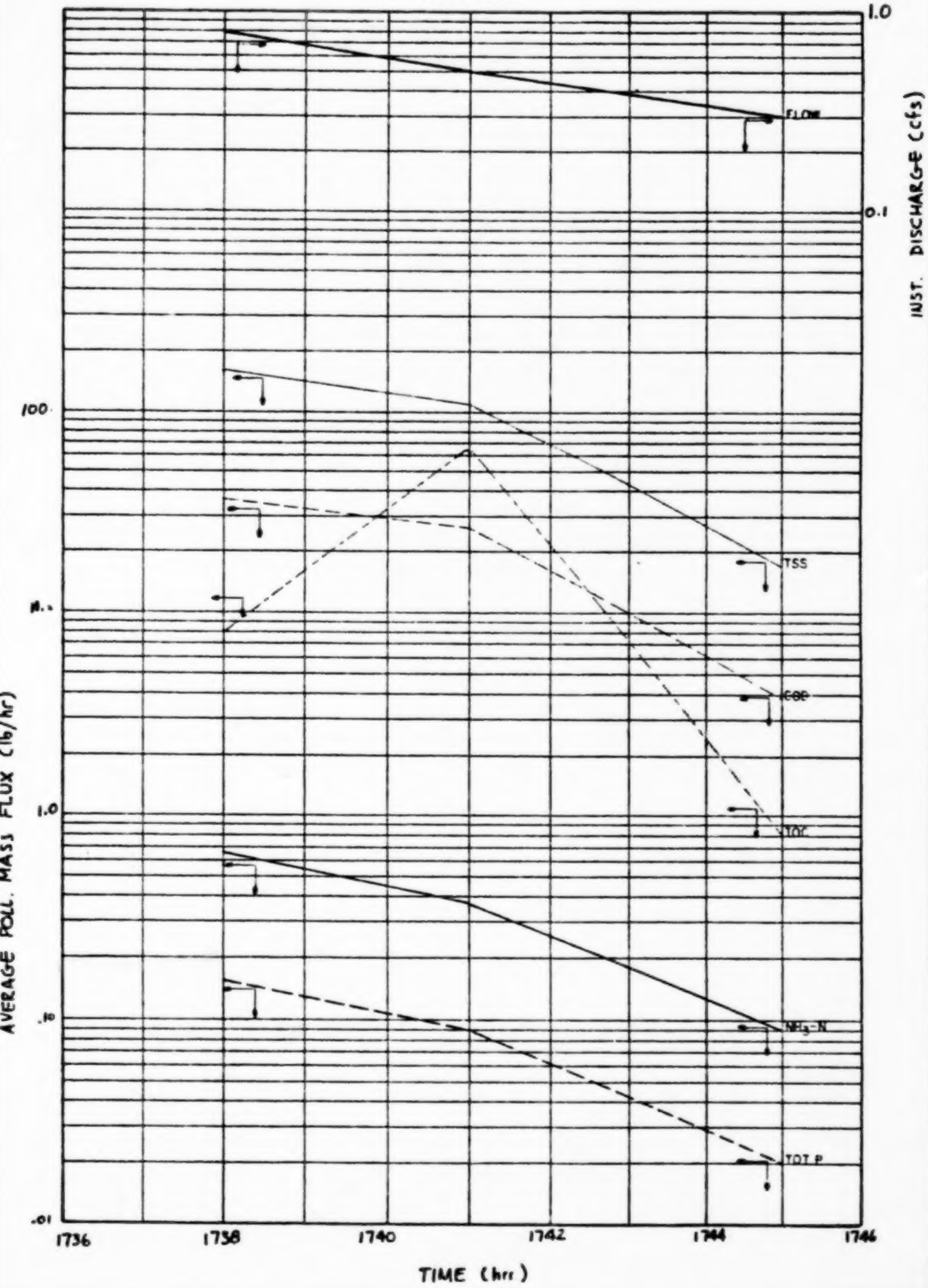
Figure C-27

ES ENGINEERING - SCIENCE

MASS FLUX
ROLLINGWOOD SITE
EVENT 08
4/17/81



CUMULATIVE MASS DISCHARGED
ROLLINGWOOD SITE
EVENT 08
4/17/81

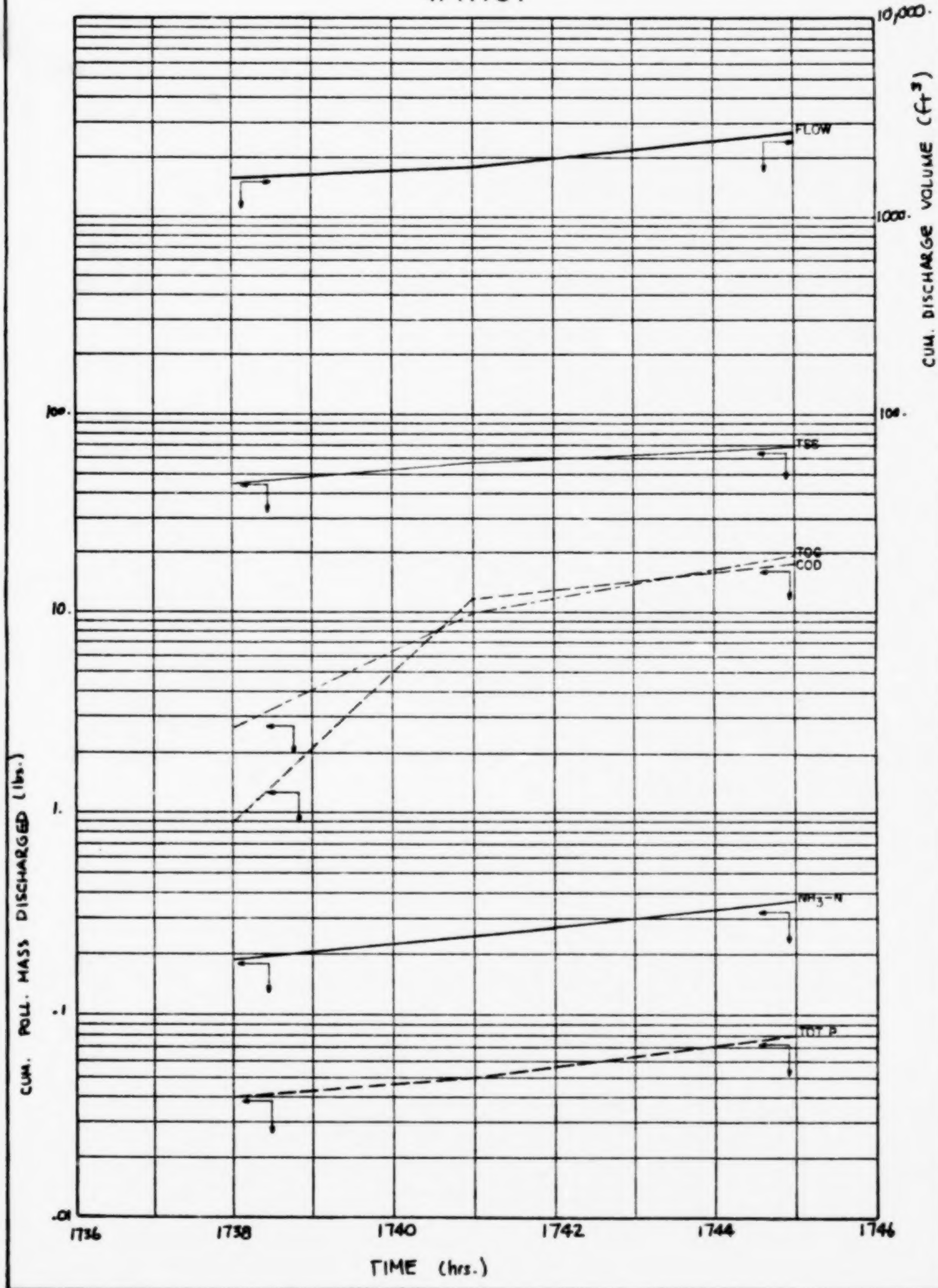


Figure C-29

ES ENGINEERING-SCIENCE

MASS FLUX
ROLLINGWOOD SITE
EVENT 14
5/16/81

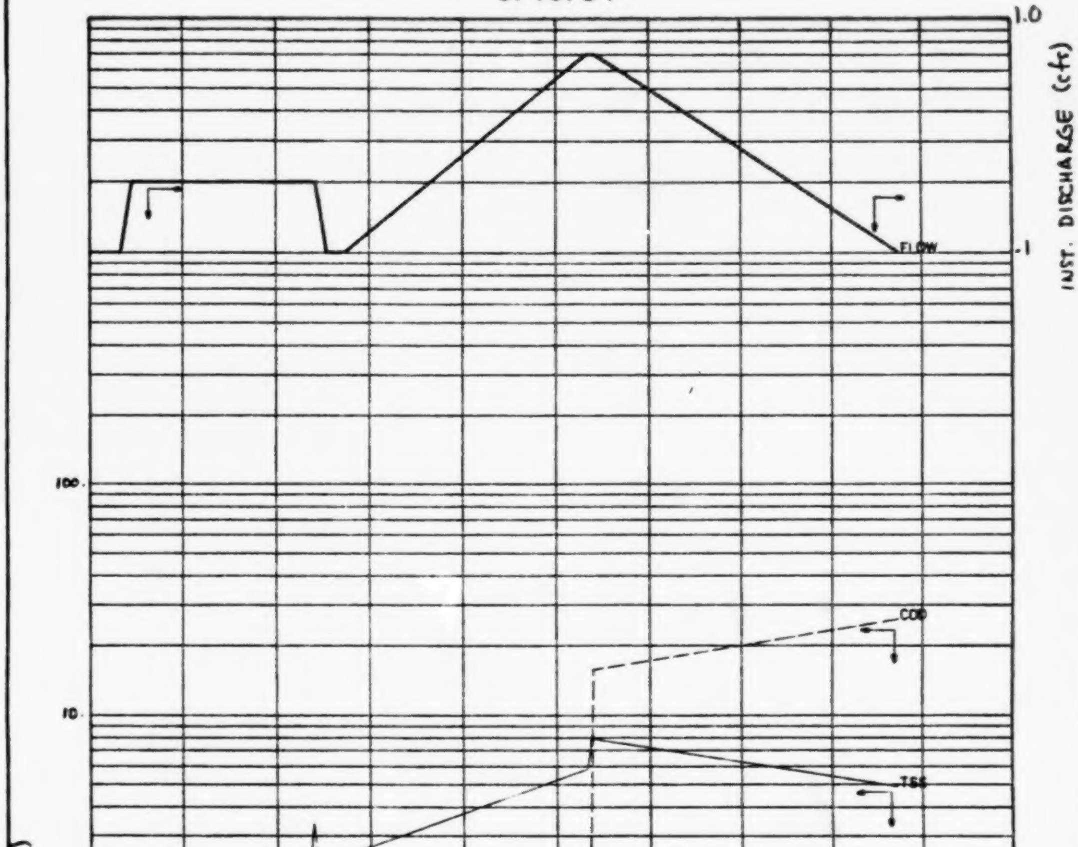


Figure C-30

ES ENGINEERING-SCIENCE

CUMULATIVE MASS DISCHARGED
ROLLINGWOOD SITE
EVENT 14
5/16/81

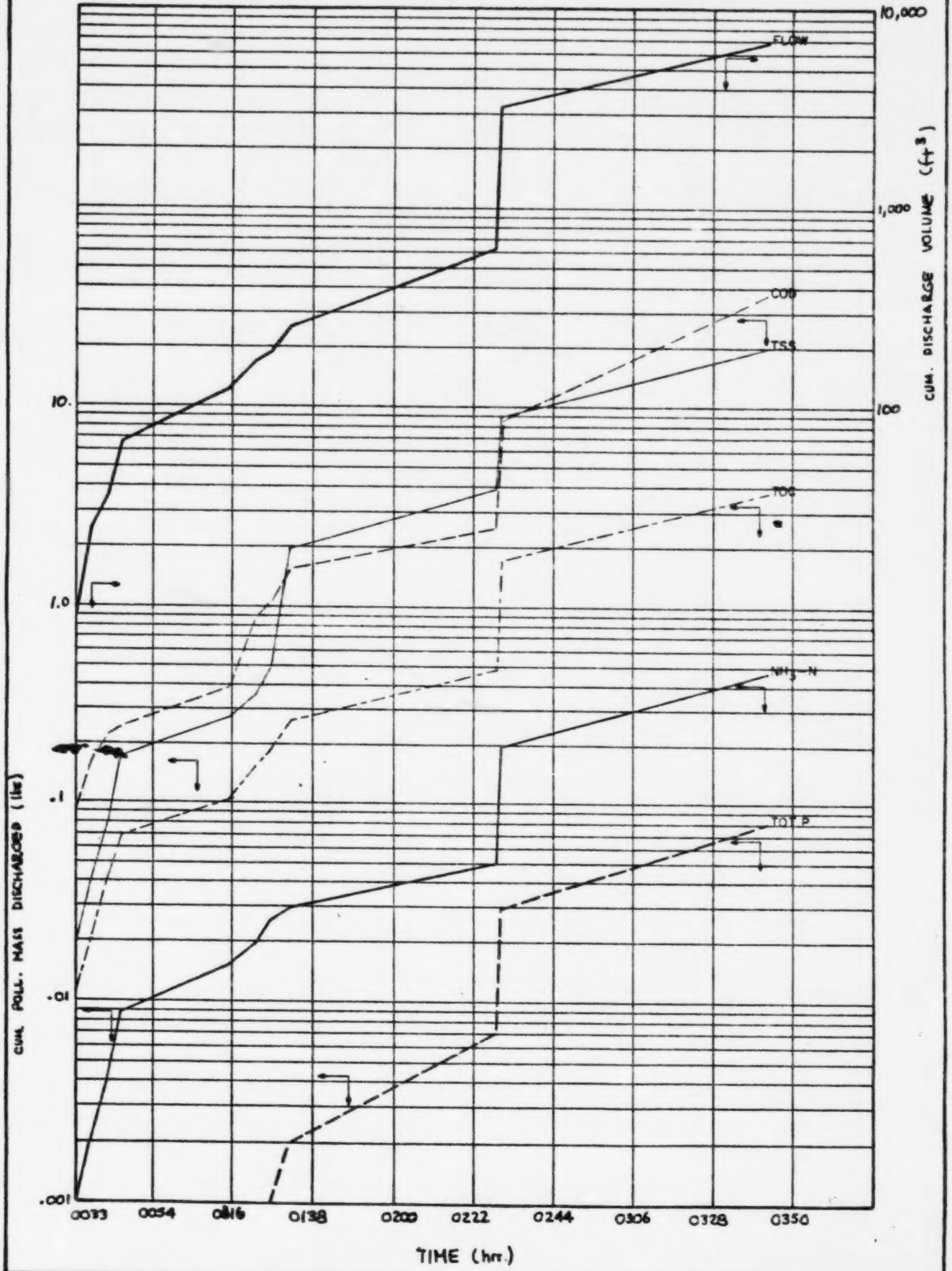


Figure C-31

MASS FLUX
ROLLINGWOOD SITE
EVENT 15
5/23/81-5/24/81

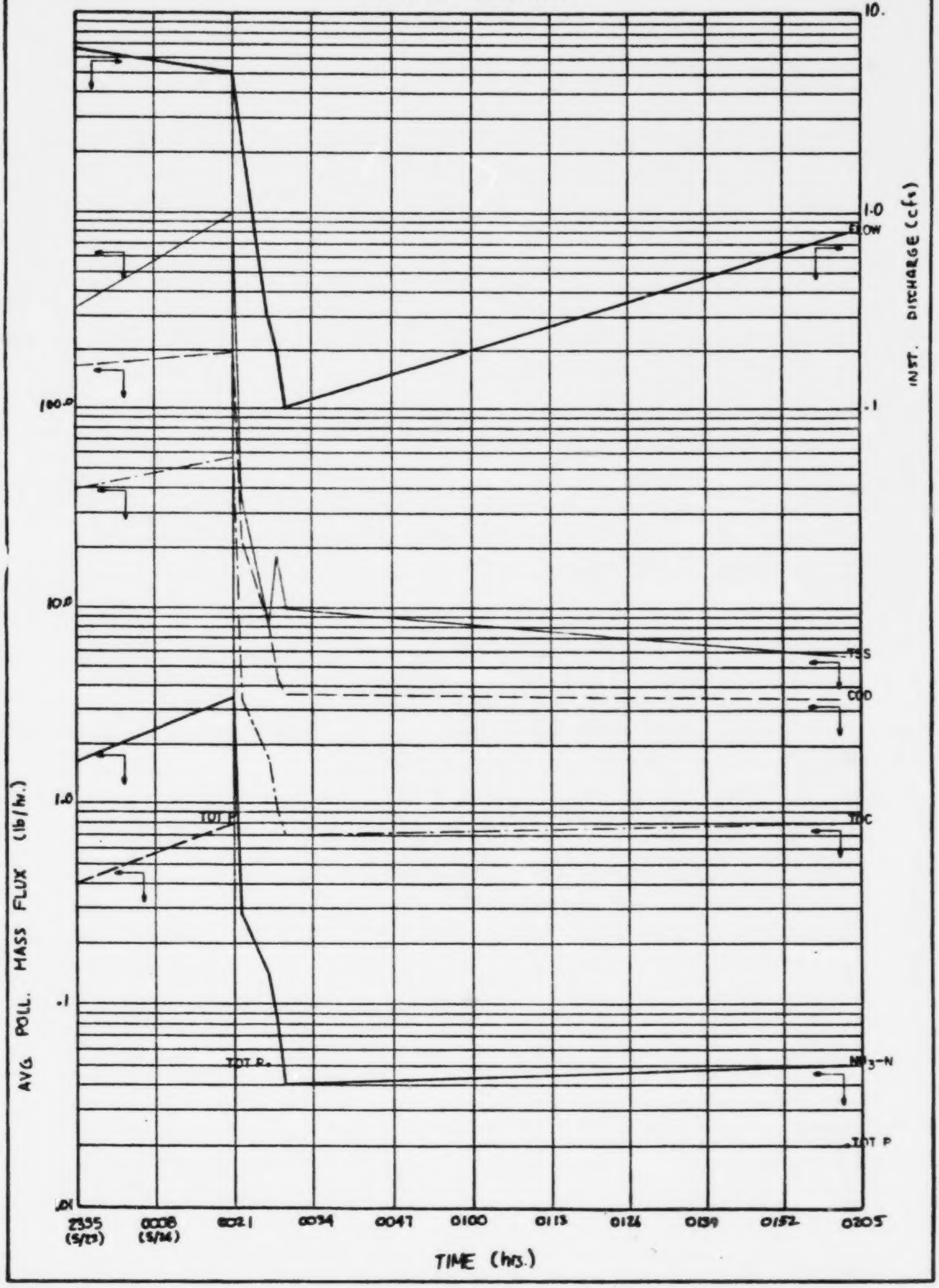
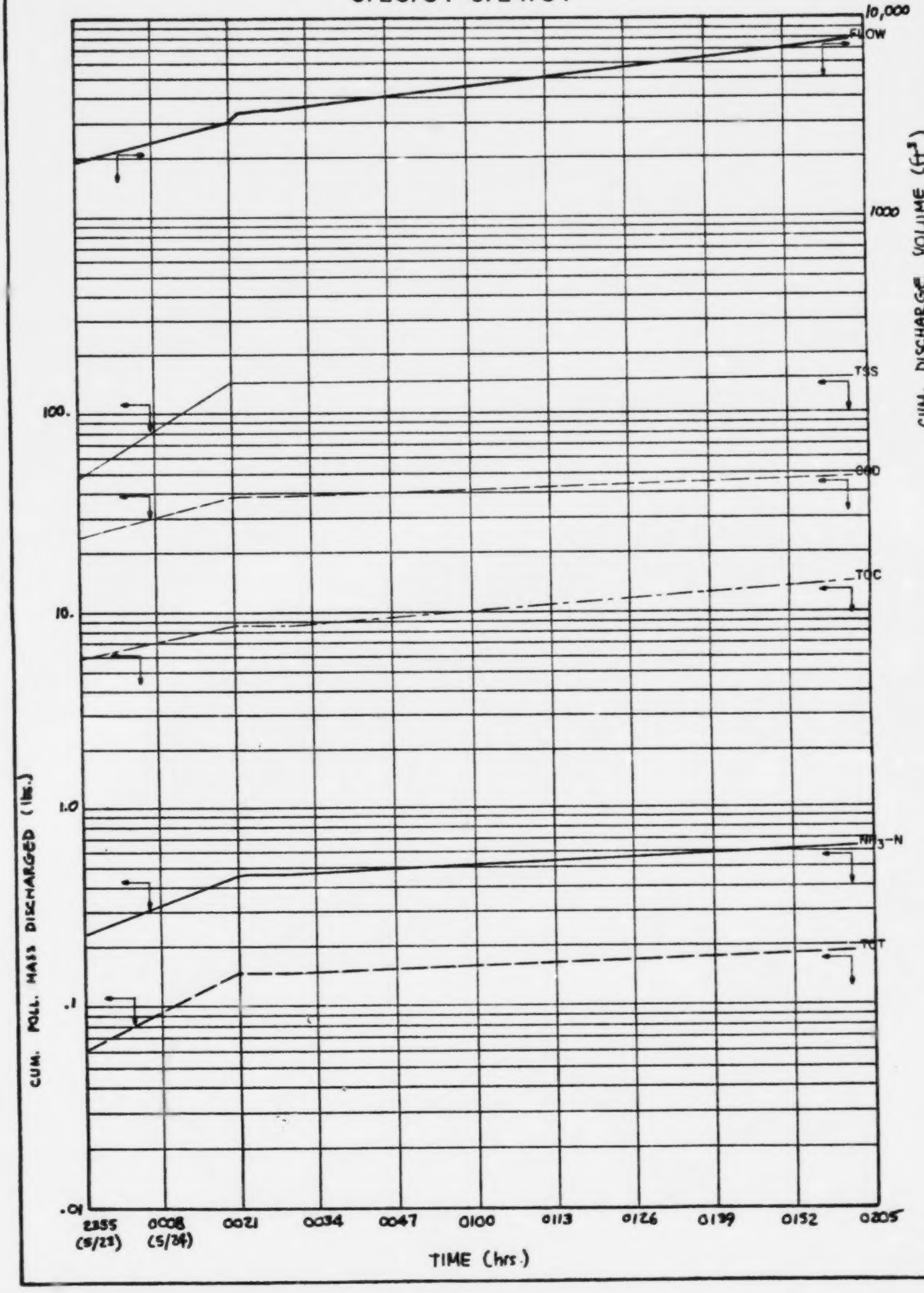
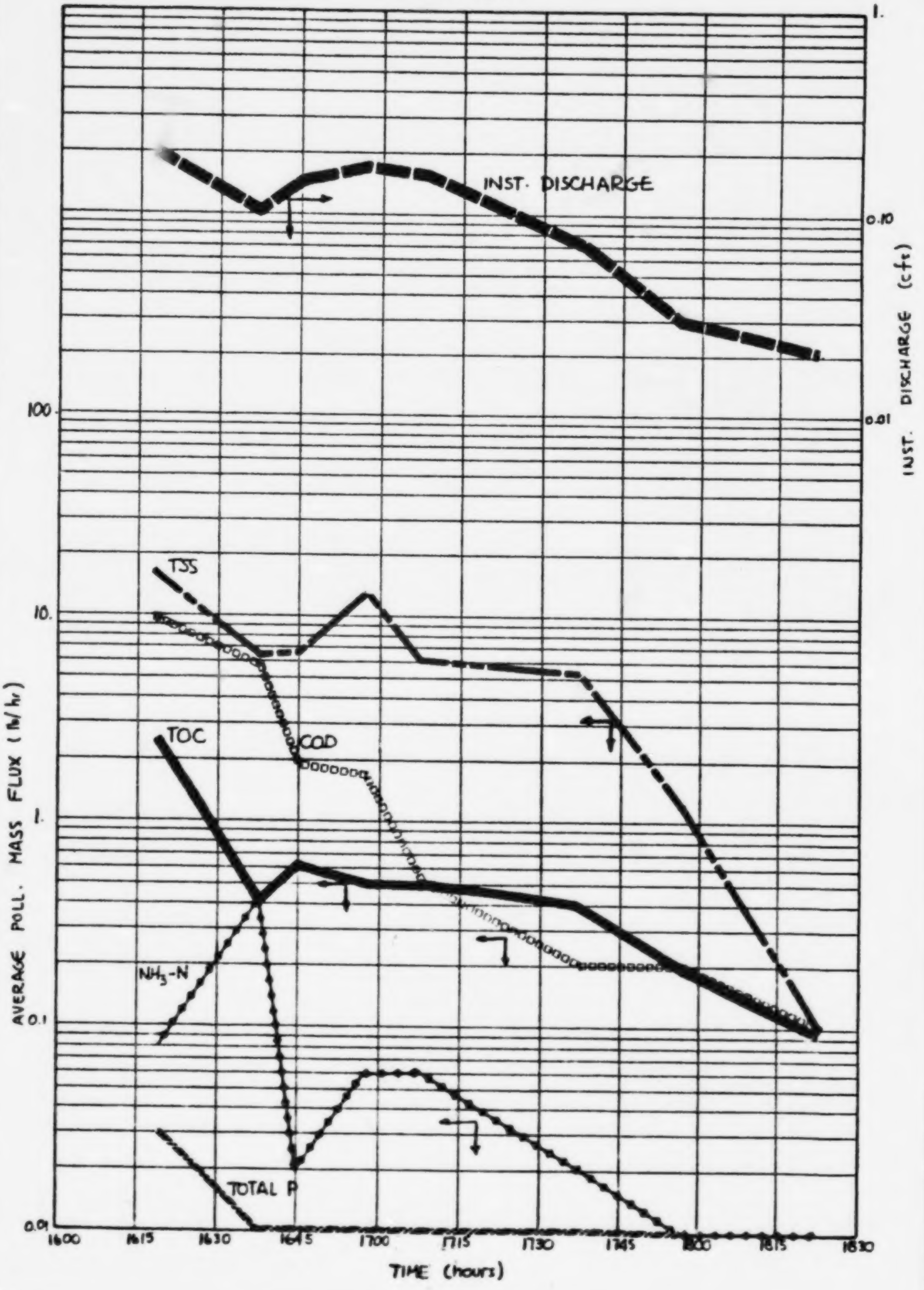


Figure C-32

CUMULATIVE MASS DISCHARGED
ROLLINGWOOD SITE
EVENT 15
5/23/81-5/24/81



MASS FLUX
ROLLINGWOOD SITE
EVENT 18
6/1/81



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CUMULATIVE MASS DISCHARGED
ROLLINGWOOD SITE
EVENT 18
6/1/81

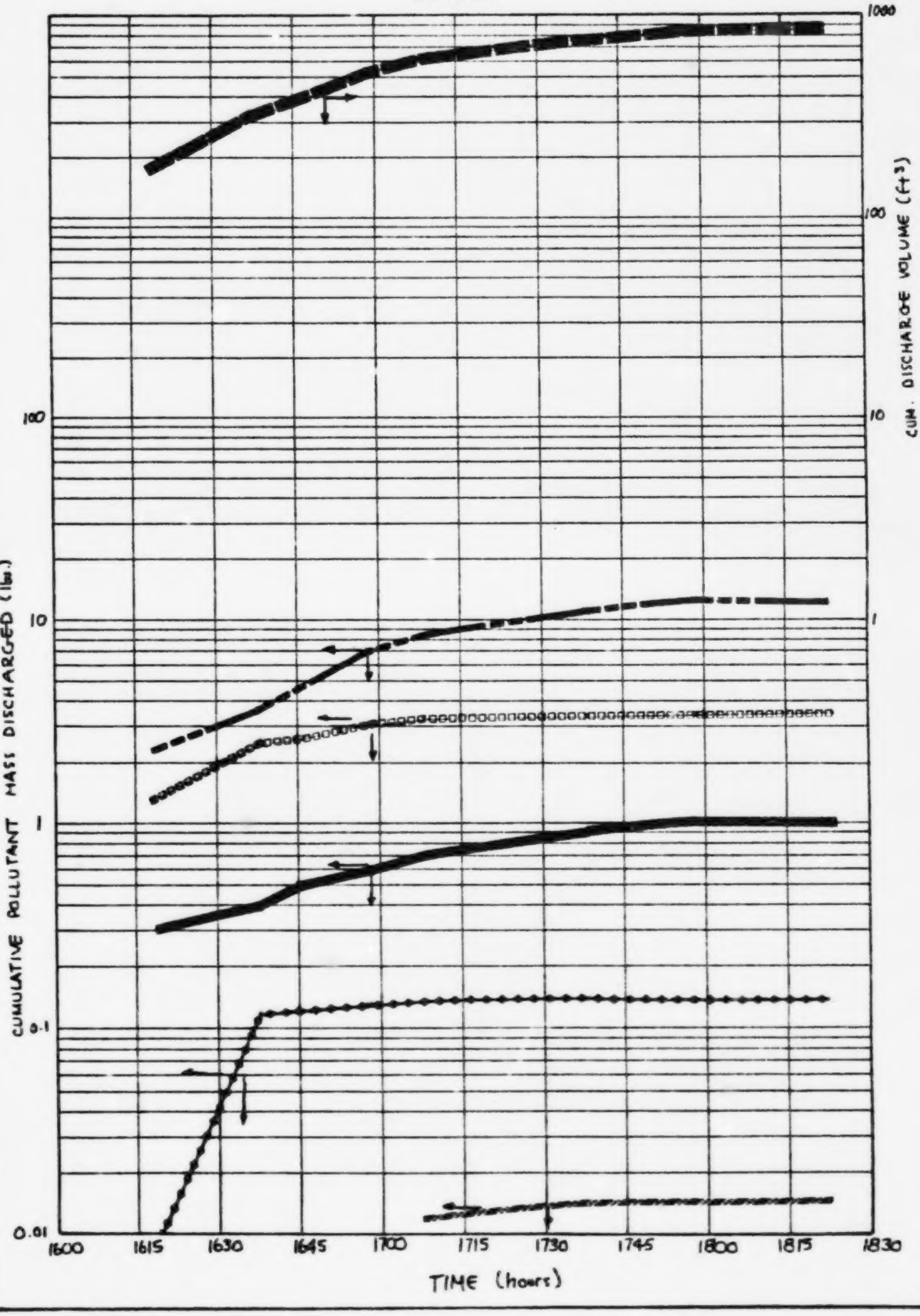


Figure C-35

ES ENGINEERING-SCIENCE

MASS FLUX
ROLLINGWOOD SITE
EVENT 19
6/2/81

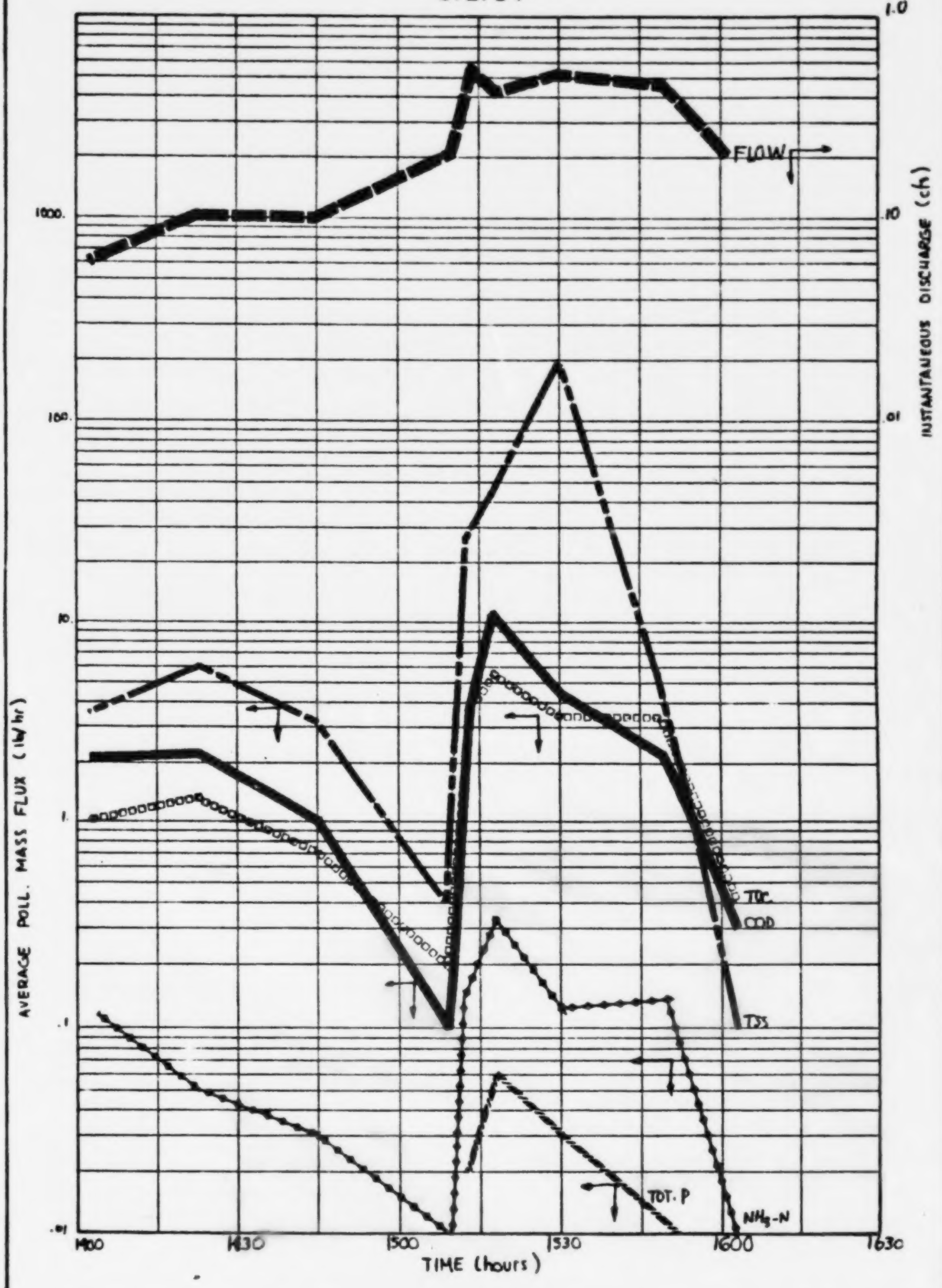
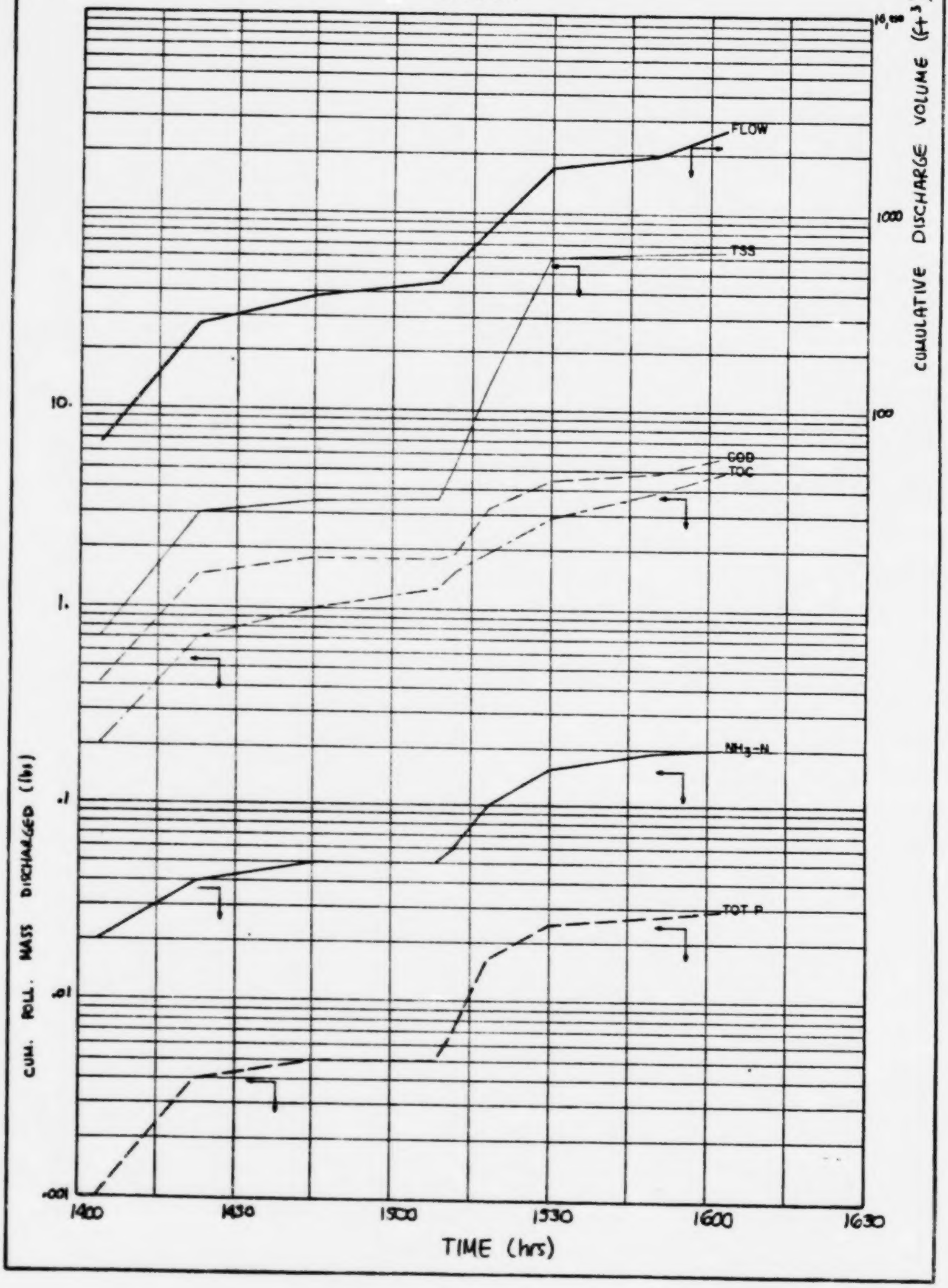


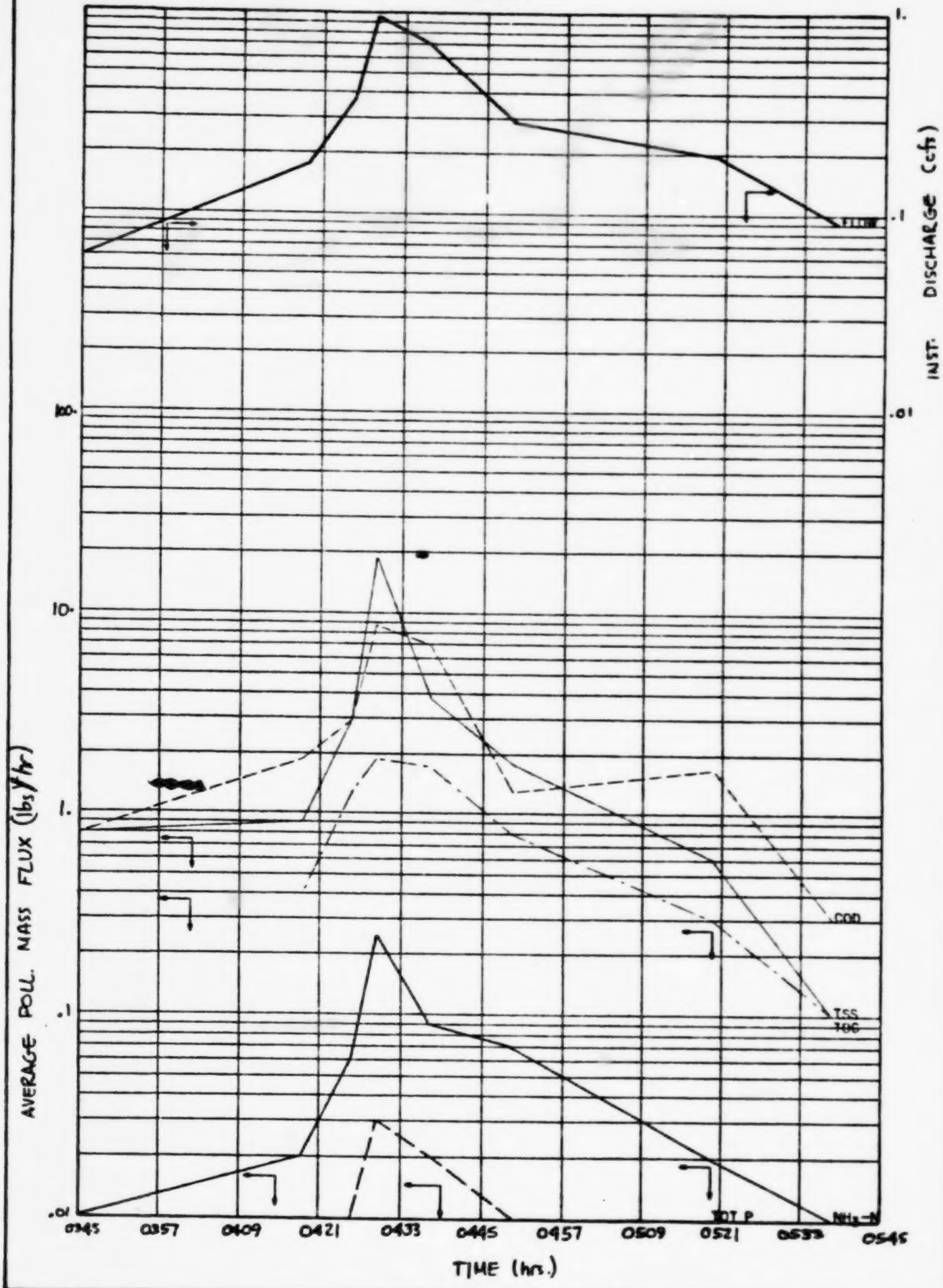
Figure C-36

ES ENGINEERING-SCIENCE

CUMULATIVE MASS DISCHARGED
ROLLINGWOOD SITE
EVENT 19
6/2/81



MASS FLUX
ROLLINGWOOD SITE
EVENT 22
6/5/81



CUMULATIVE MASS DISCHARGED
ROLLINGWOOD SITE
EVENT 22
6/5/81

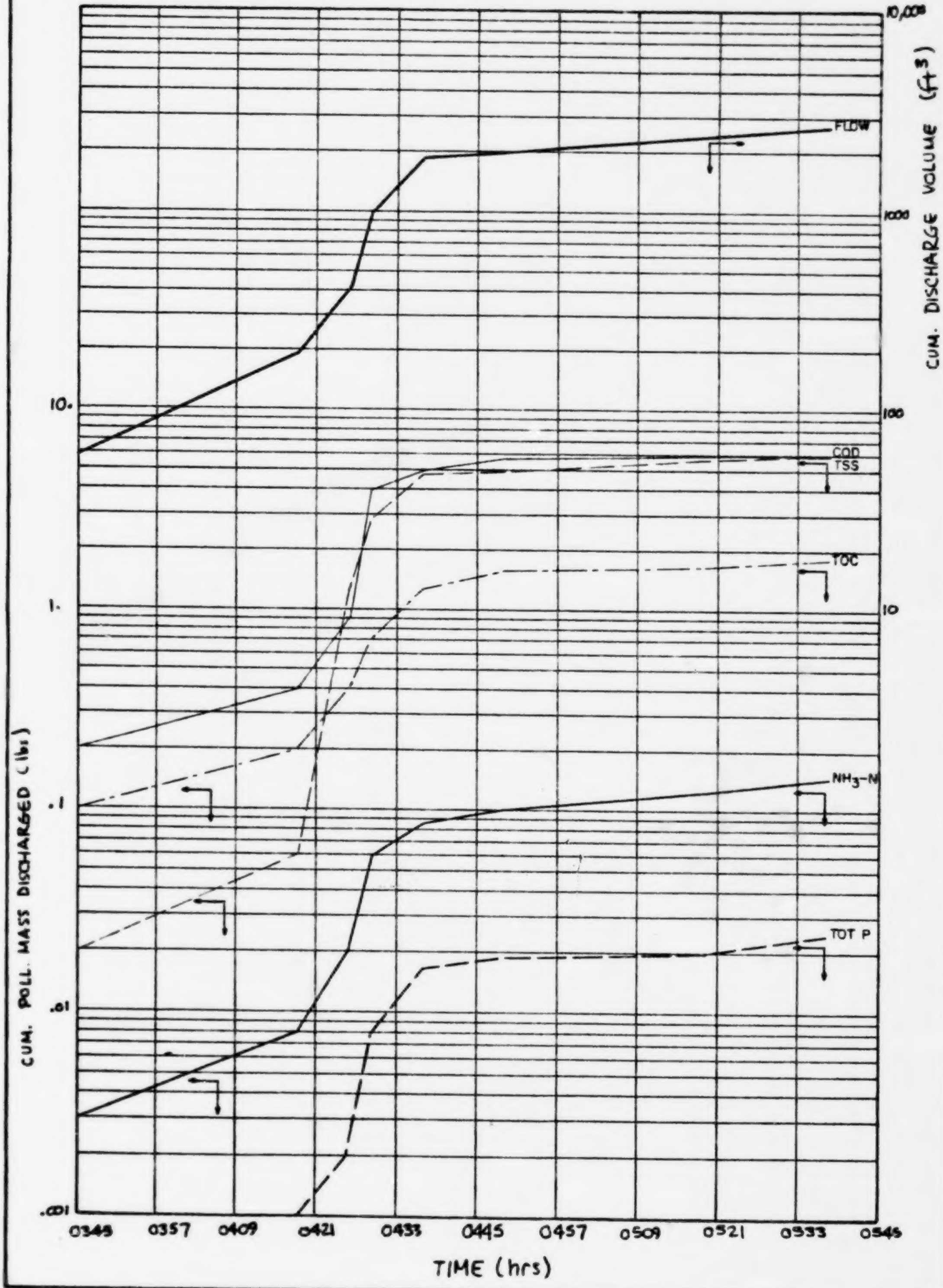
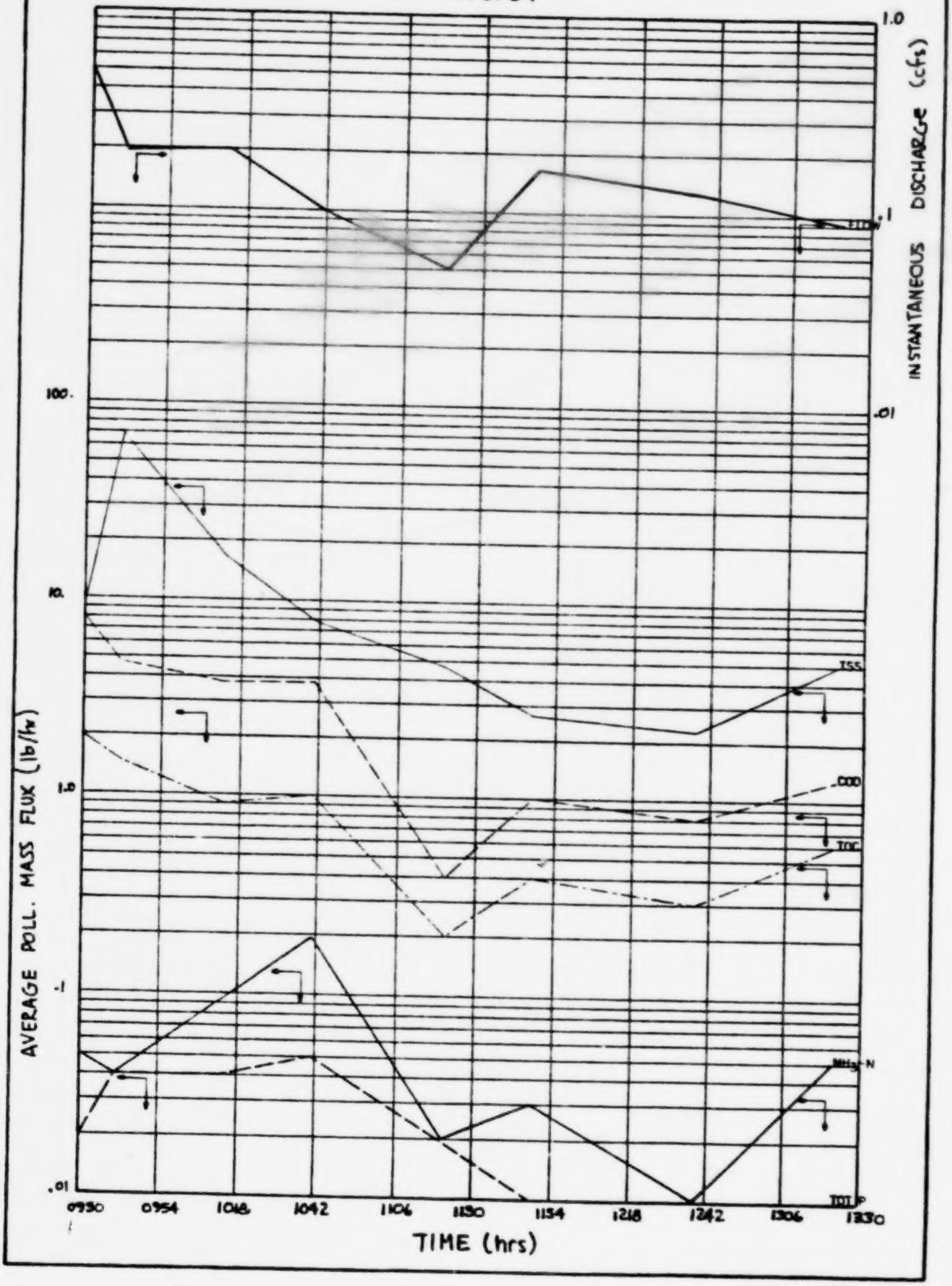


Figure C-39

MASS FLUX
ROLLINGWOOD SITE
EVENT 25
7/5/81



CUMULATIVE MASS DISCHARGED
ROLLINGWOOD SITE
EVENT 25
7/5/81

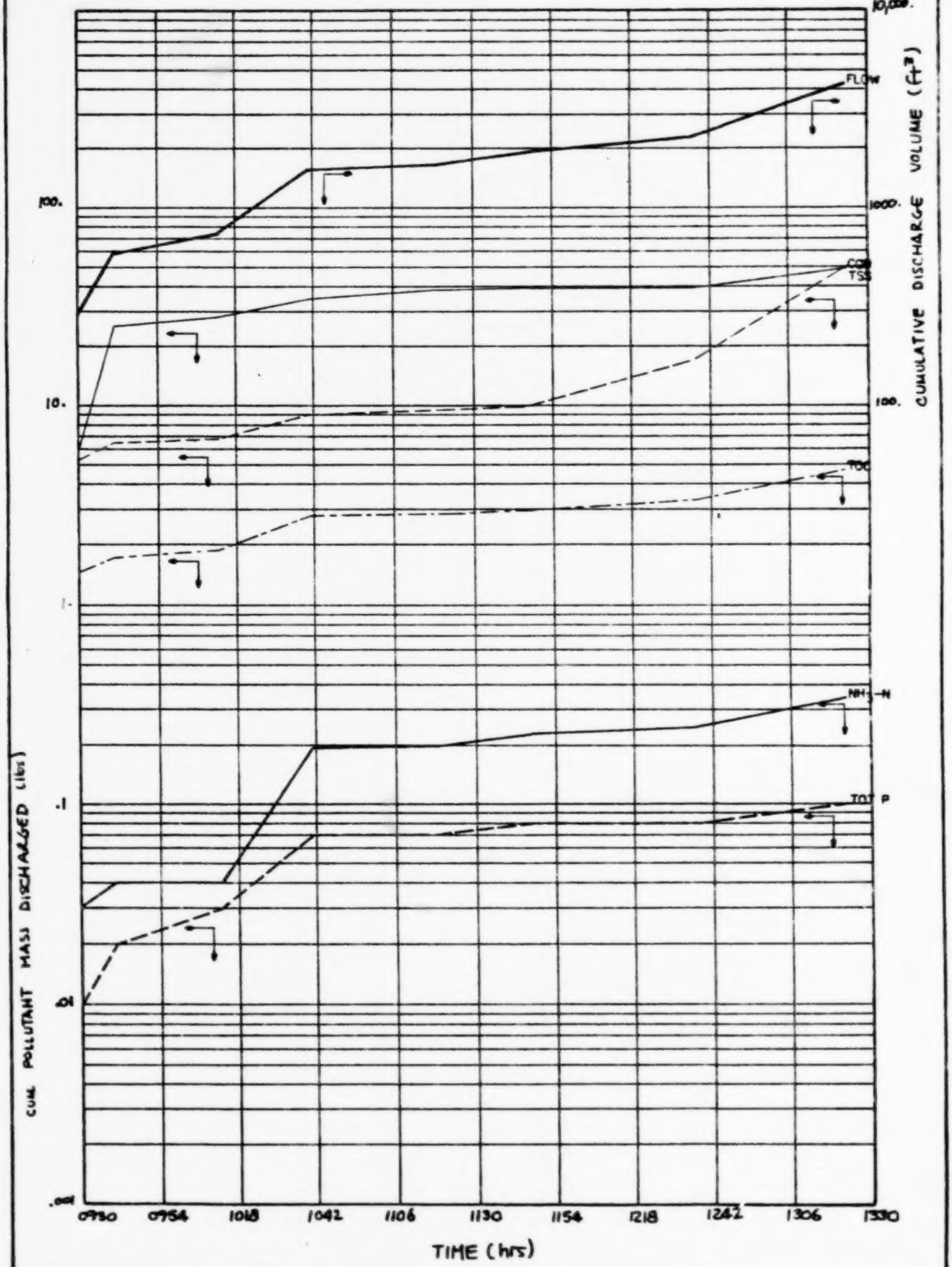


Figure C-41

ES ENGINEERING-SCIENCE

MASS FLUX
ROLLINGWOOD SITE
EVENT 31
8/17/81

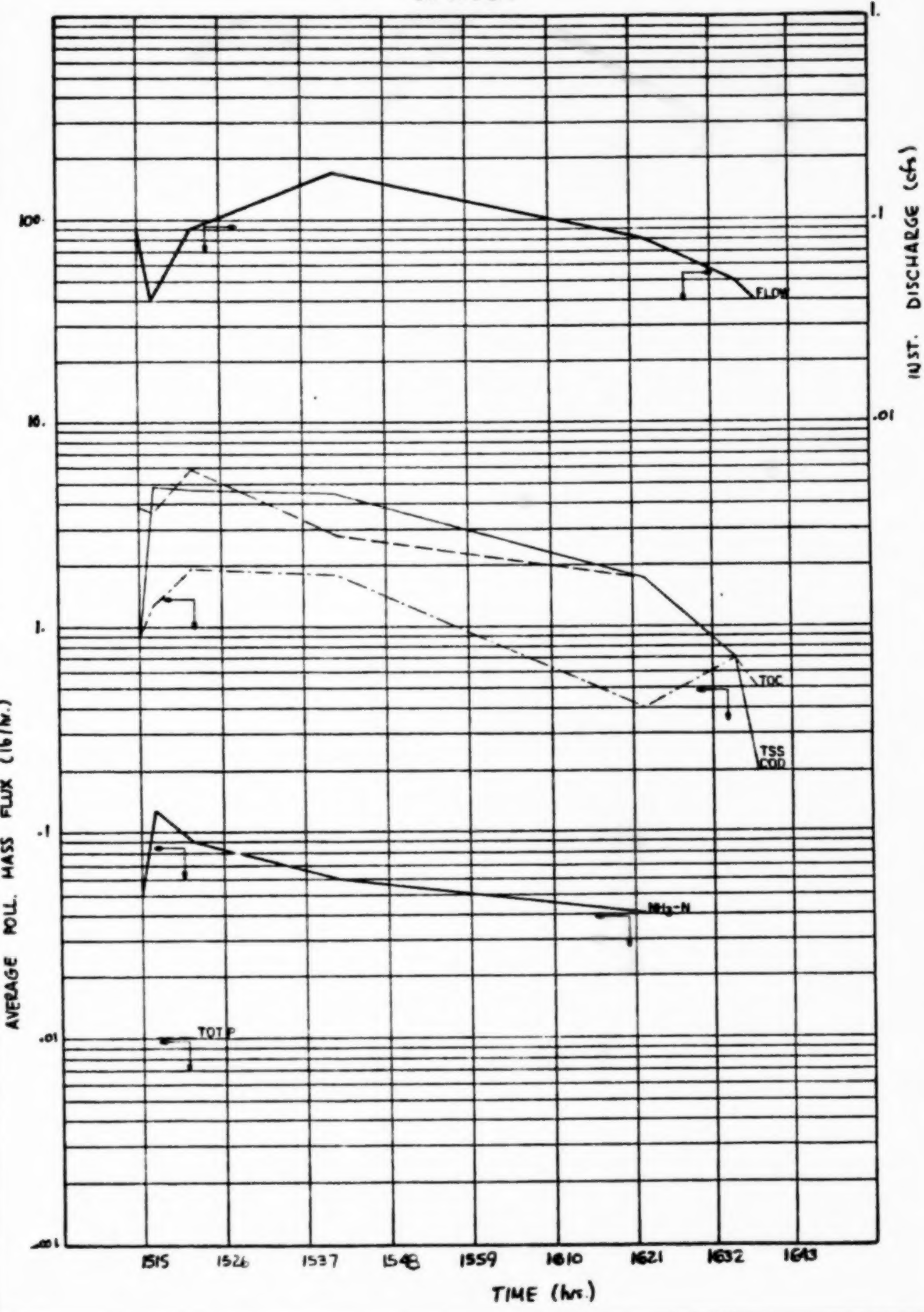


Figure C-42

ES ENGINEERING-SCIENCE

CUMULATIVE MASS DISCHARGED
ROLLINGWOOD SITE
EVENT 31
8/17/81

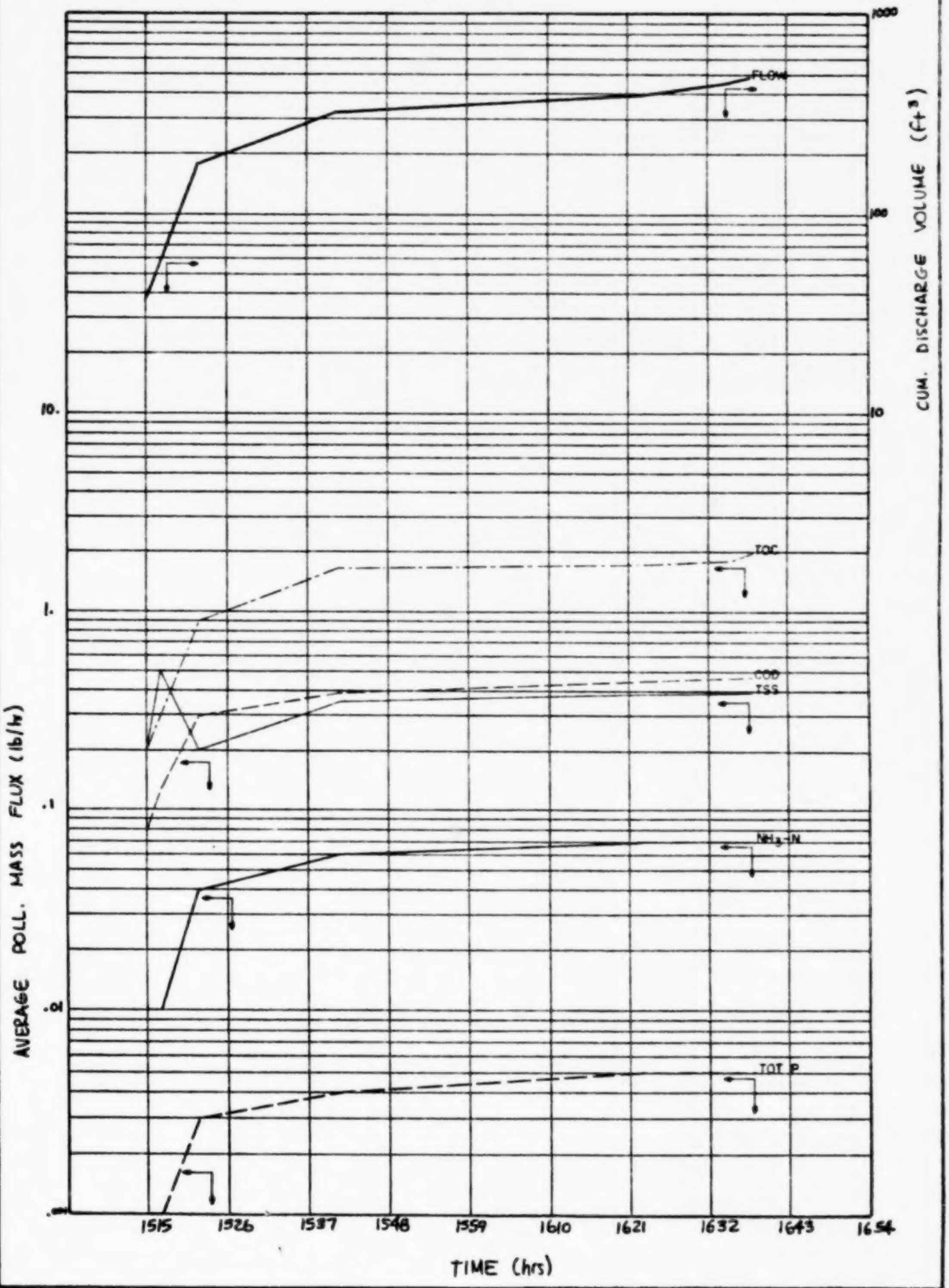


Figure C-43

ES ENGINEERING-SCIENCE

MASS FLUX
WOODHOLLOW DAM SITE
EVENT 05
3/7/81

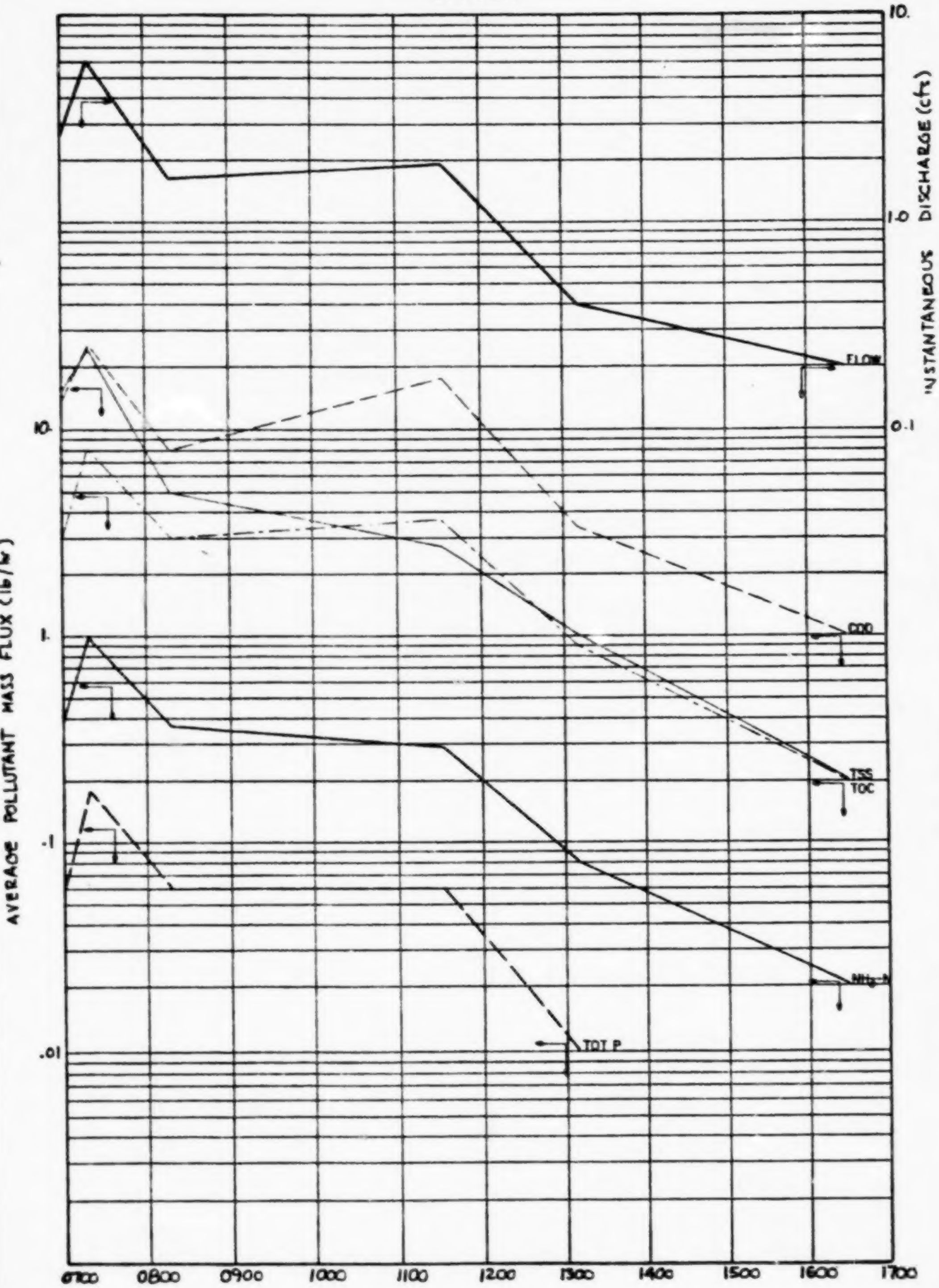
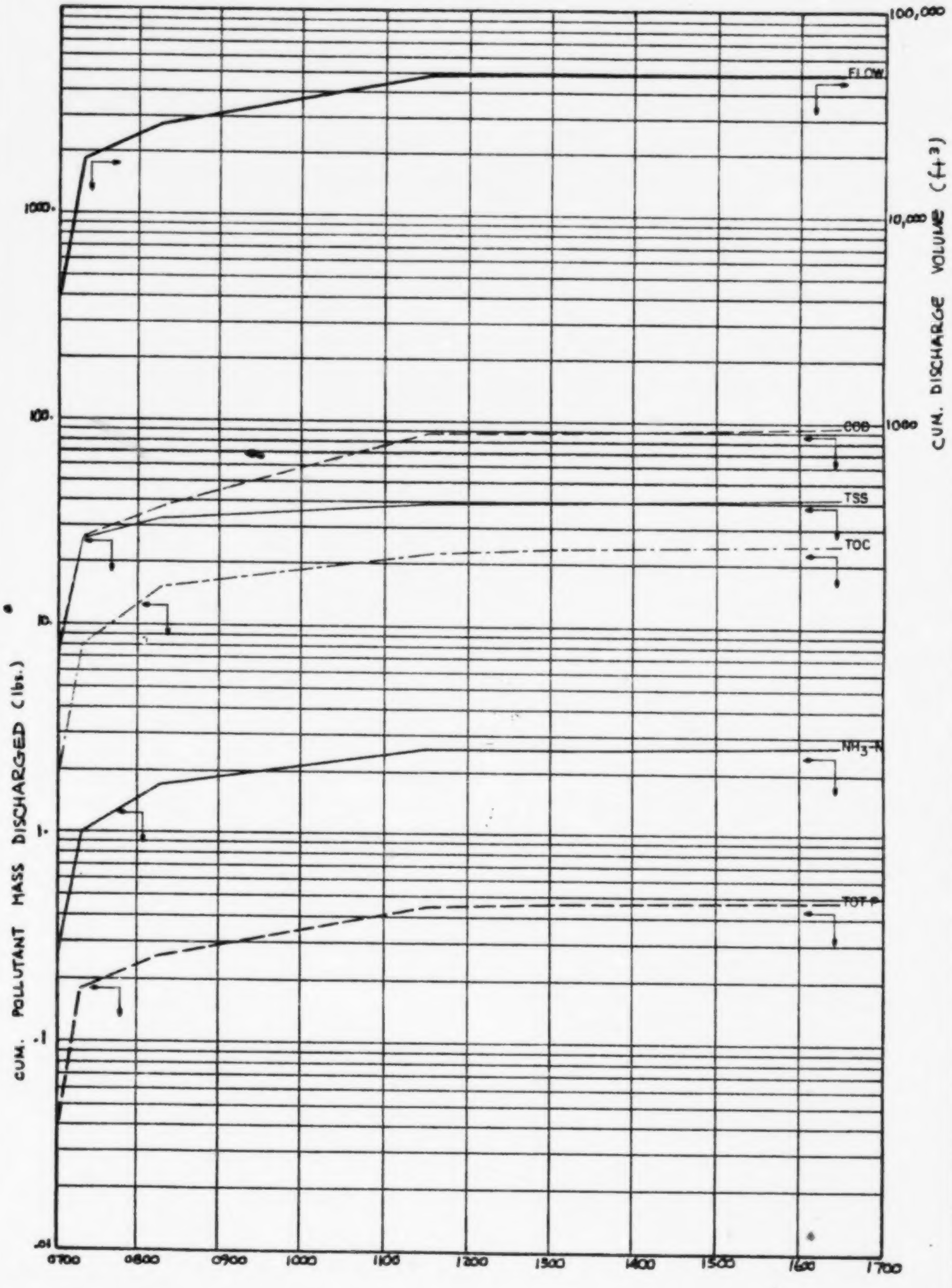


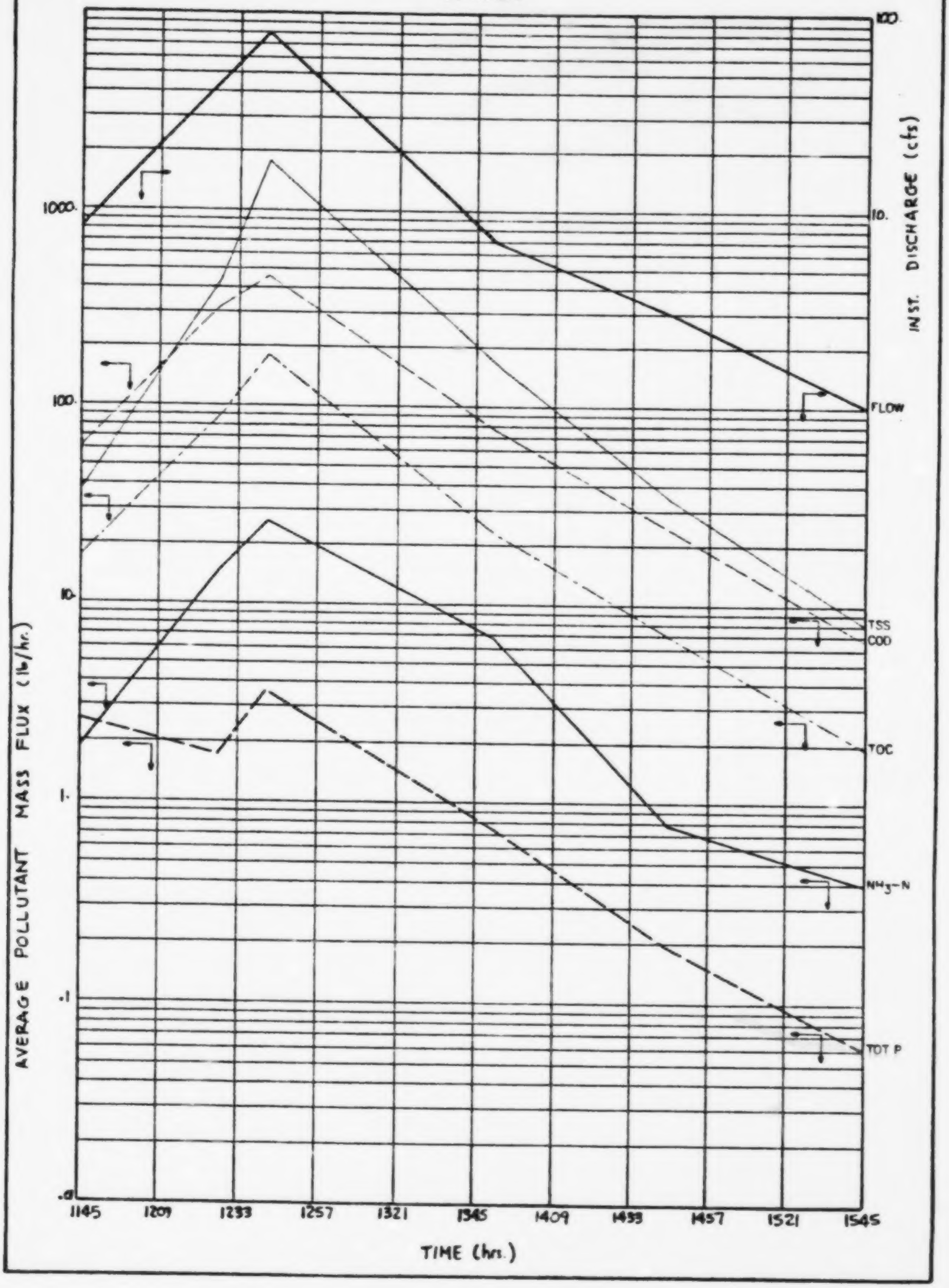
Figure C-44

ES ENGINEERING - SCIENCE

CUMULATIVE MASS DISCHARGED
WOODHOLLOW DAM SITE
EVENT 05
3/7/81



MASS FLUX
WOODHOLLOW DAM SITE
EVENT 12
5/1/81



ES ENGINEERING - SCIENCE

CUMULATIVE MASS DISCHARGED WOODHOLLOW DAM SITE
EVENT 12
5/1/81

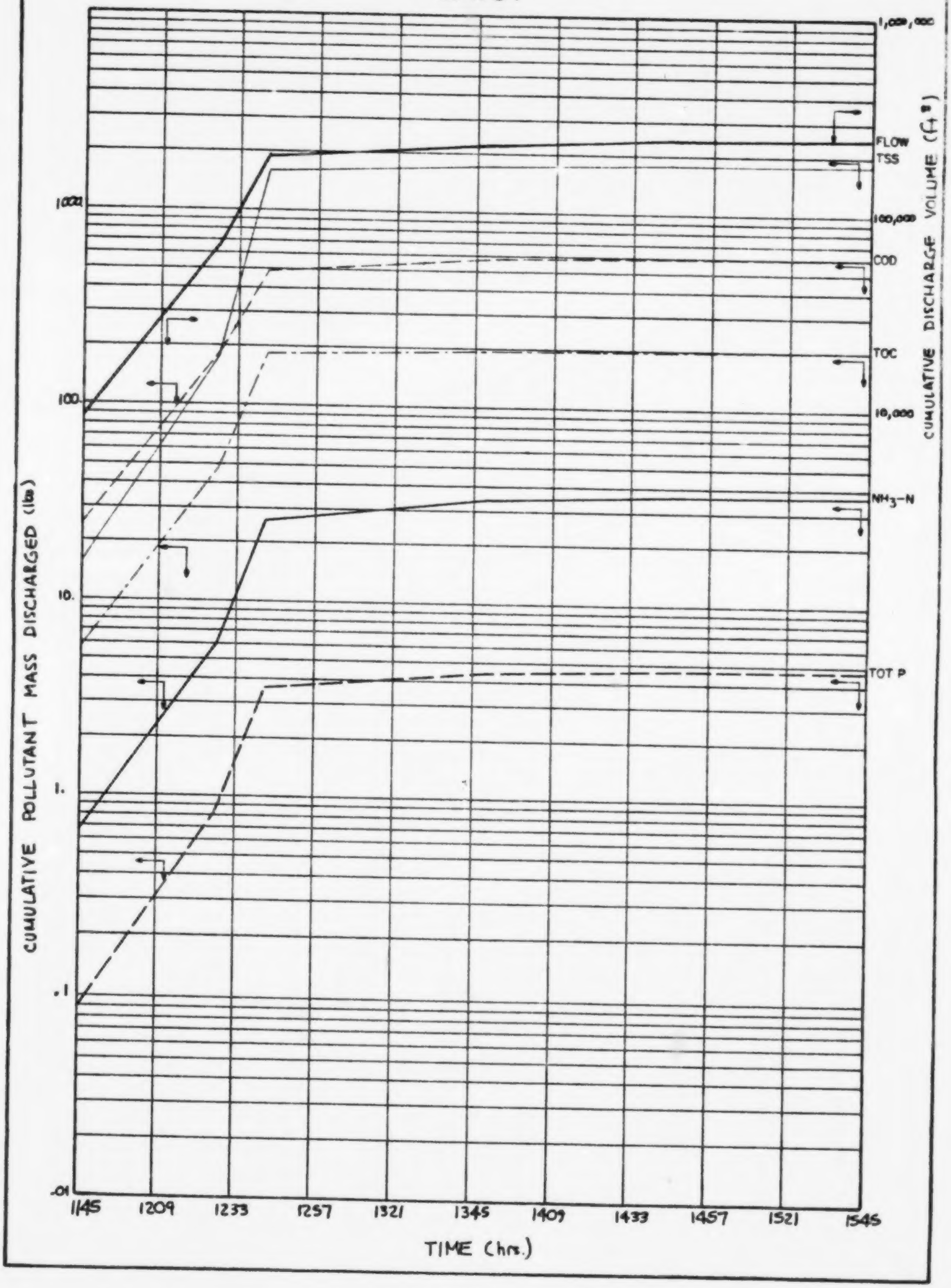
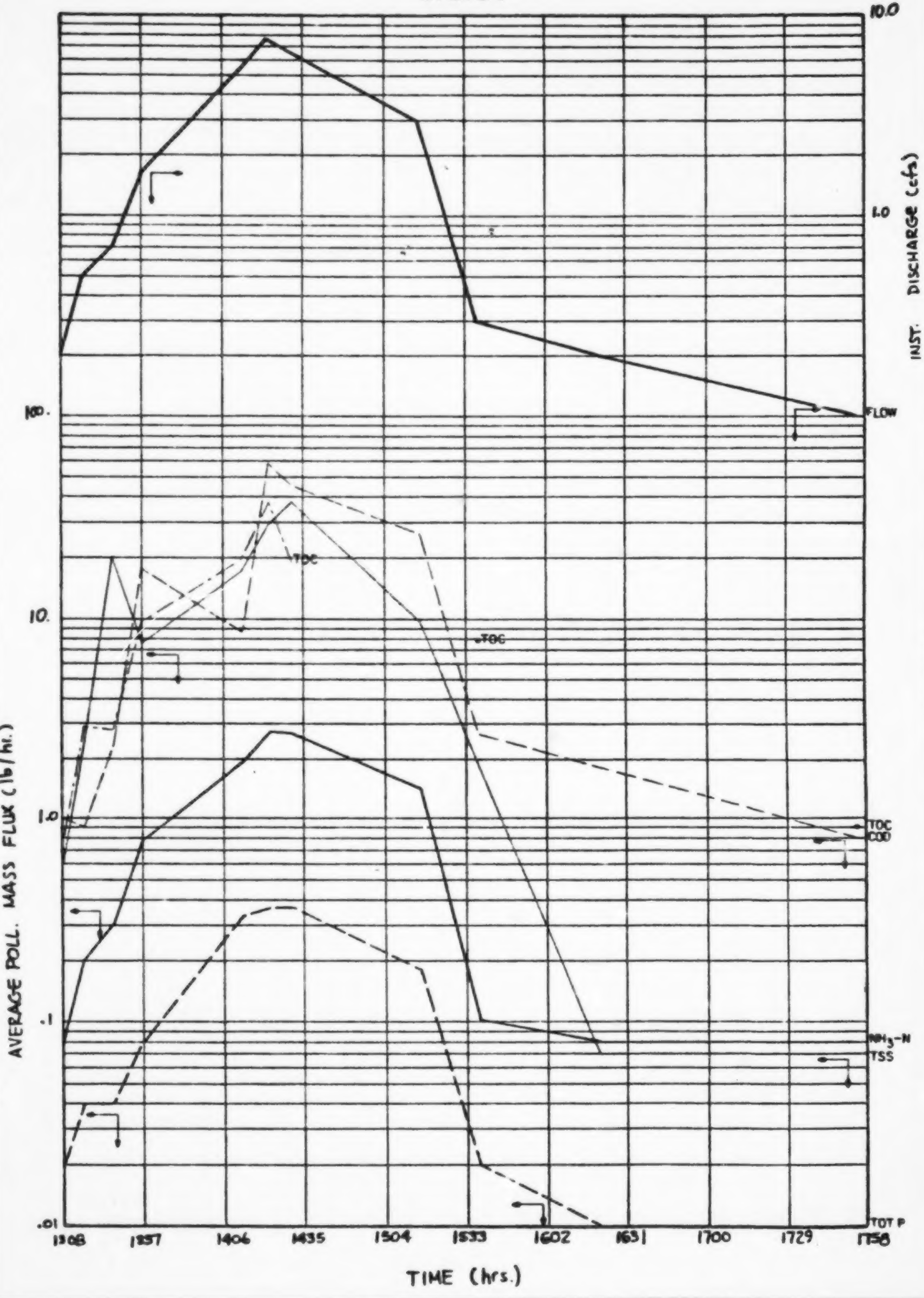


Figure C-47

ES ENGINEERING-SCIENCE

MASS FLUX
WOODHOLLOW DAM SITE
EVENT 13
5/2/81



3..7

Figure C-48

CUMULATIVE MASS DISCHARGED
WOODHOLLOW DAM SITE
EVENT 13
5/2/81

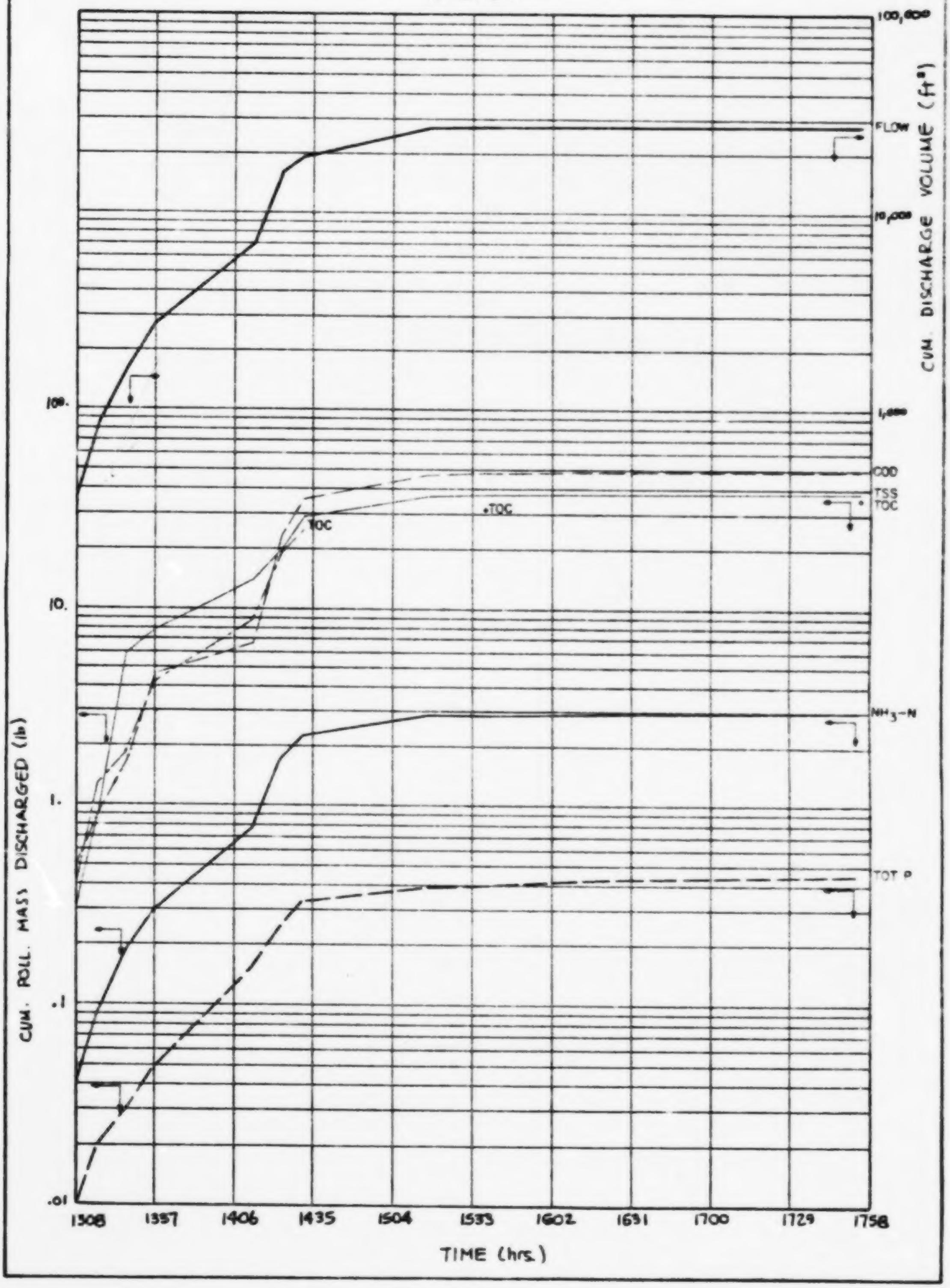


Figure C-49

MASS FLUX
WOODHOLLOW DAM SITE
EVENT 34
9/14/81

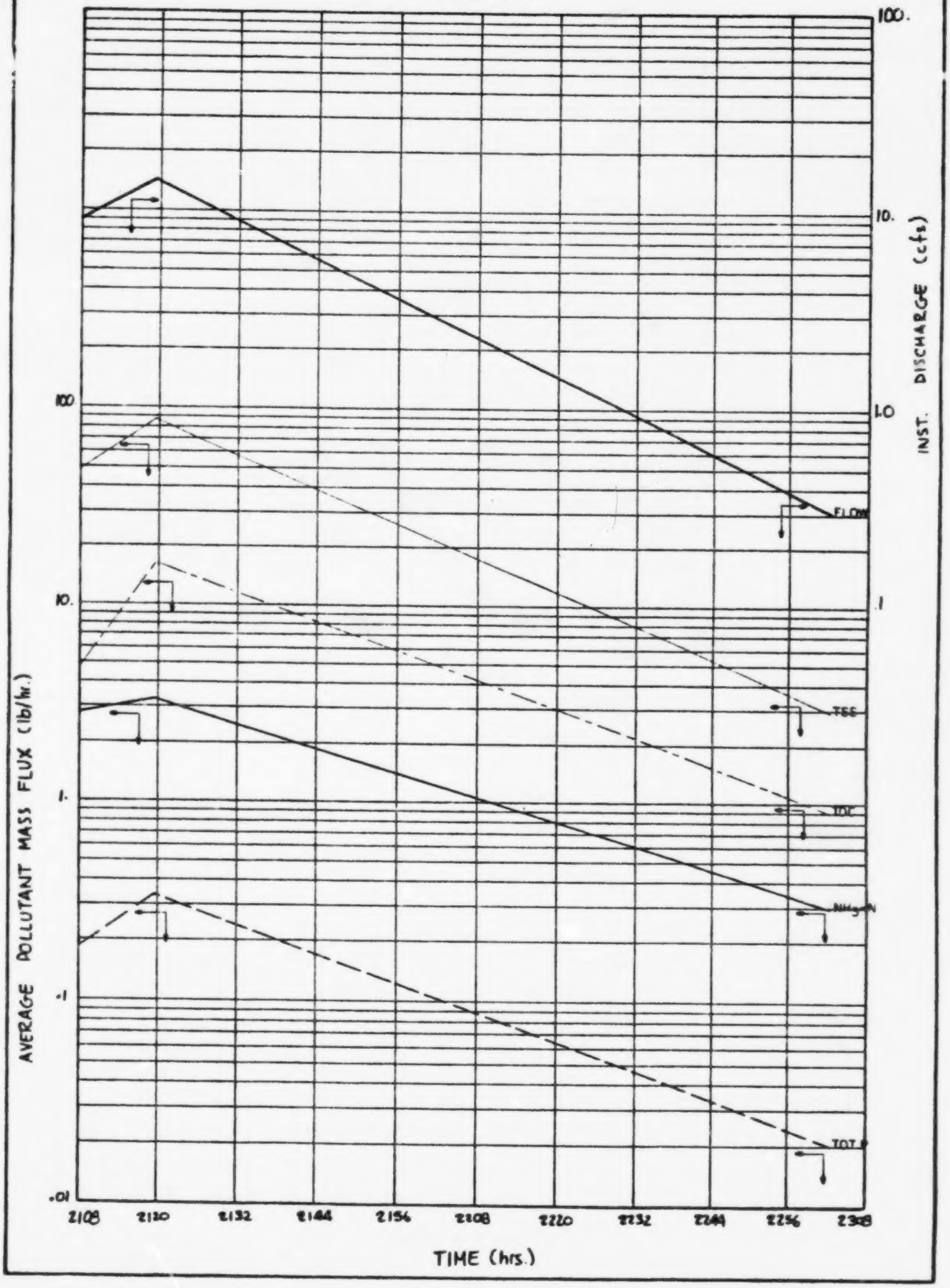


Figure C-50

ES ENGINEERING-SCIENCE

CUMULATIVE MASS DISCHARGED
WOODHOLLOW DAM SITE
EVENT 34
9/14/81

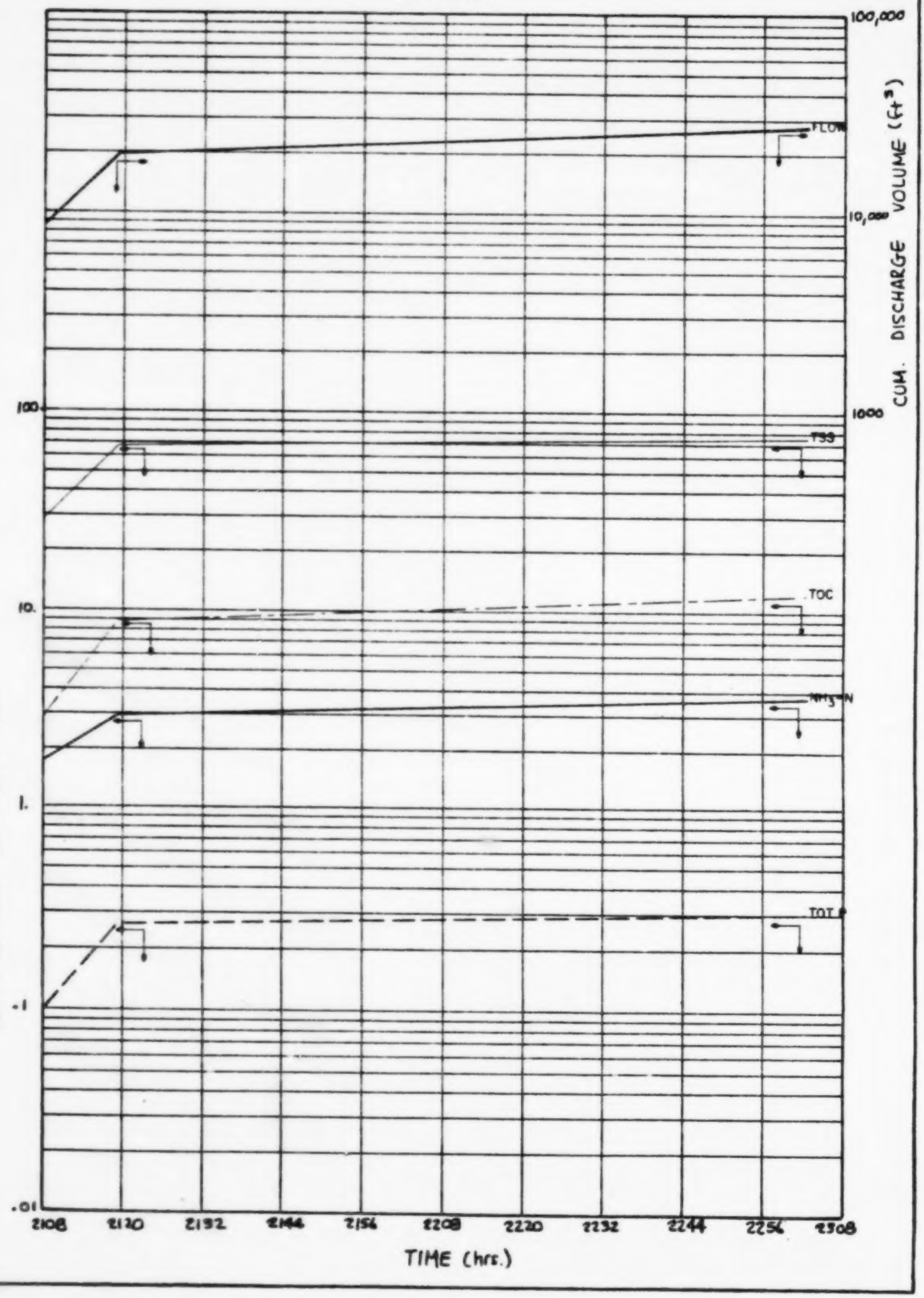
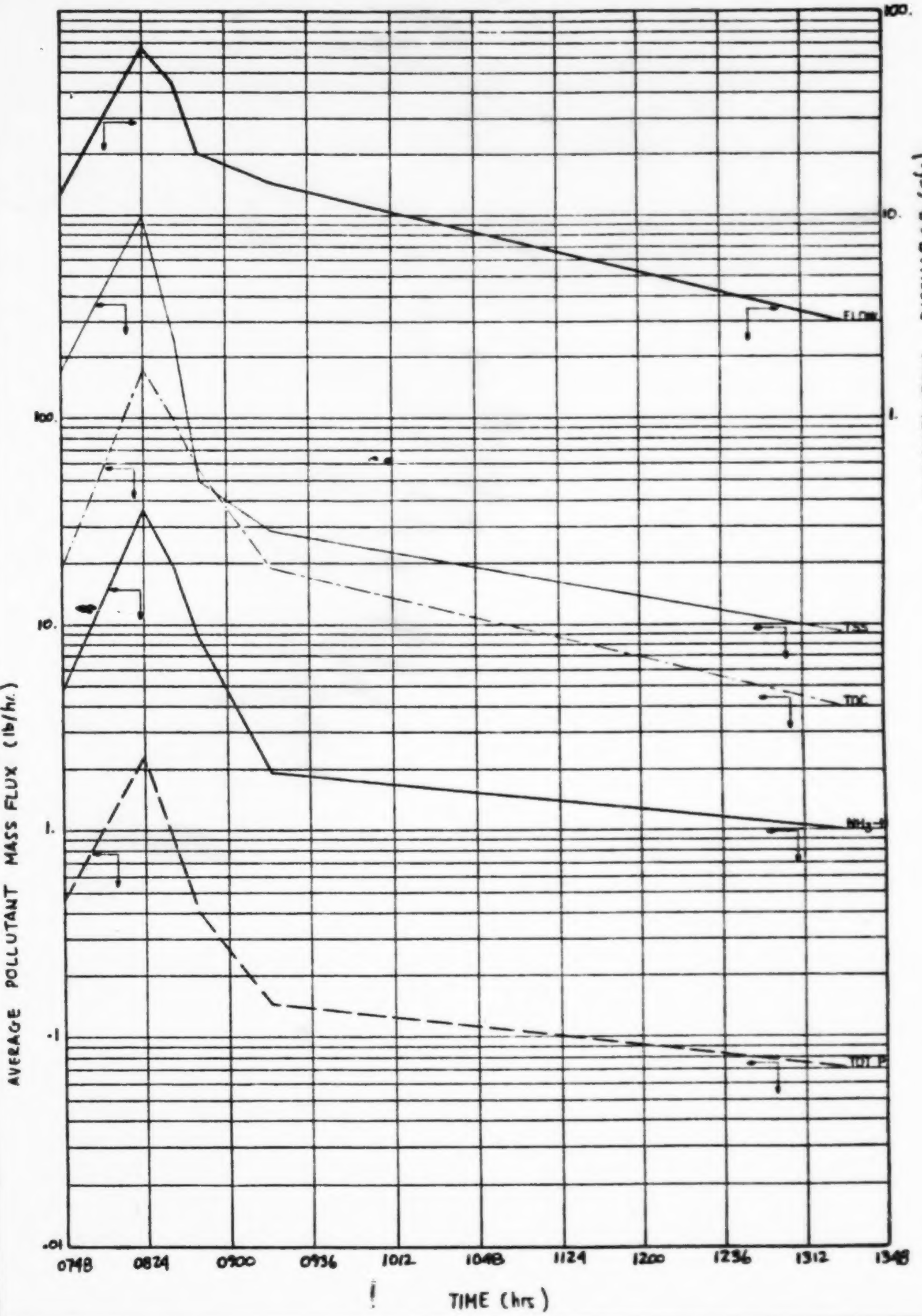


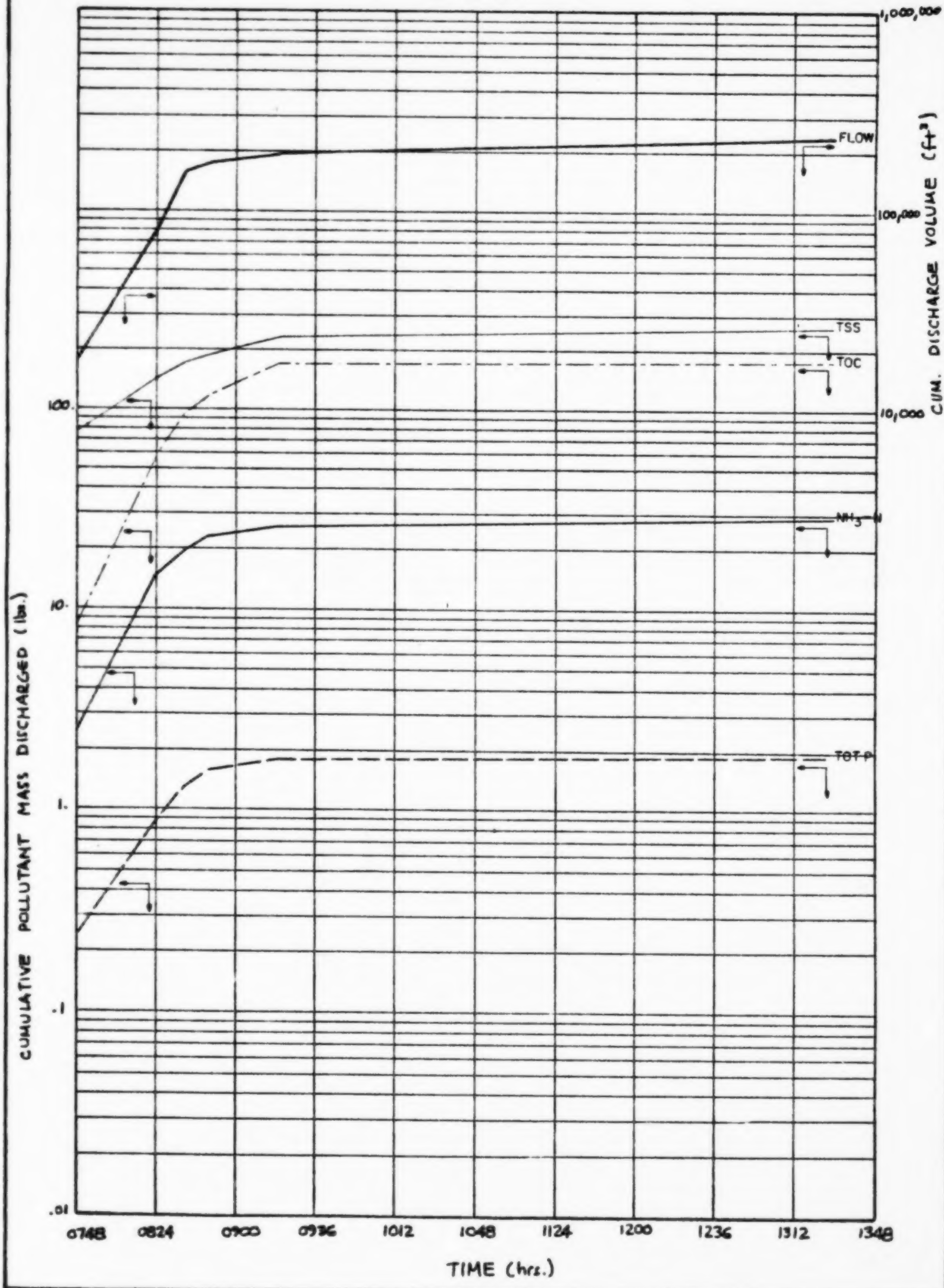
Figure C-51

ES ENGINEERING-SCIENCE

MASS FLUX
WOODHOLLOW DAM SITE
EVENT 35
9/15/81



CUMULATIVE MASS DISCHARGED
WOODHOLLOW DAM SITE
EVENT 35
9/15/81



APPENDIX D

STORM-AVERAGE CONCENTRATIONS FOR POLLUTANTS MEASURED IN STORM WATER RUNOFF FROM TEST WATERSHEDS NORTHWEST AUSTIN (HART LANE) AND ROLLINGWOOD SURVEY SITES

TABLE D-1

STORM-AVERAGE CONCENTRATIONS FOR POLLUTANTS MEASURED IN STORM WATER RUNOFF FROM TEST WATERSHEDS SURVEY YEAR 1981

Date	Watershed	Discharge (ft^3)	Storm Average Concentrations				
			COD (mg/l)	TOC (mg/l)	NH_3-N (mg/l)	Total P (mg/l)	TSS (mg/l)
2/04	NWA	3,520	16	7.1	0.59	-	42
2/10	NWA	42,034	137	39.0	1.89	0.24	201
3/07	NWA	45,128	34	7.1	1.21	0.19	43
3/12	NWA	58,724	53	11.7	0.86	0.11	17
3/28	NWA	12,904	96	45.9	3.19	0.88	316
4/17	NWA	54,088	210	-	2.79	1.00	334
5/16	NWA	78,024	63	-	2.21	0.31	153
5/23	NWA	129,307	83	16.9	1.32	0.44	272
6/01	NWA	15,626	34	8.0	0.88	0.14	84
6/02	NWA	65,230	97	15.9	1.60	0.33	183
6/03	NWA	45,230	48	8.5	0.90	0.17	34
8/29	NWA	23,407	-	15.6	-	0.17	46
8/30	NWA	40,503	-	8.7	-	0.09	9
9/14	NWA	33,768	-	23.8	-	0.35	227
9/15	NWA	92,580	-	10.9	-	0.25	42
4/17	RW	2,573	102	67.8	2.12	0.50	431
5/16	RW	6,829	83	8.6	1.03	0.19	47
5/23	RW	5,737	133	32.6	1.73	0.47	378
6/01	RW	901	59	18.2	0.82	0.27	197
6/02	RW	2,671	36	11.2	1.31	0.17	371
6/05	RW	2,452	39	10.5	0.78	0.14	37
6/25	RW	13,784	52	13.5	0.50	0.12	82
7/05	RW	4,248	57	16.7	1.22	0.35	180
8/07	RW	478	63	145.2	2.18	0.17	130

NOTES: NWA = Northwest Austin (Hart Lane) site.
RW = Rollingwood site.

APPENDIX E

EXAMPLE CALCULATION FOR THE DETERMINATION OF POLLUTANT STORM-AVERAGE CONCENTRATIONS

APPENDIX E

EXAMPLE CALCULATION FOR THE DETERMINATION OF POLLUTANT STORM-AVERAGE CONCENTRATIONS

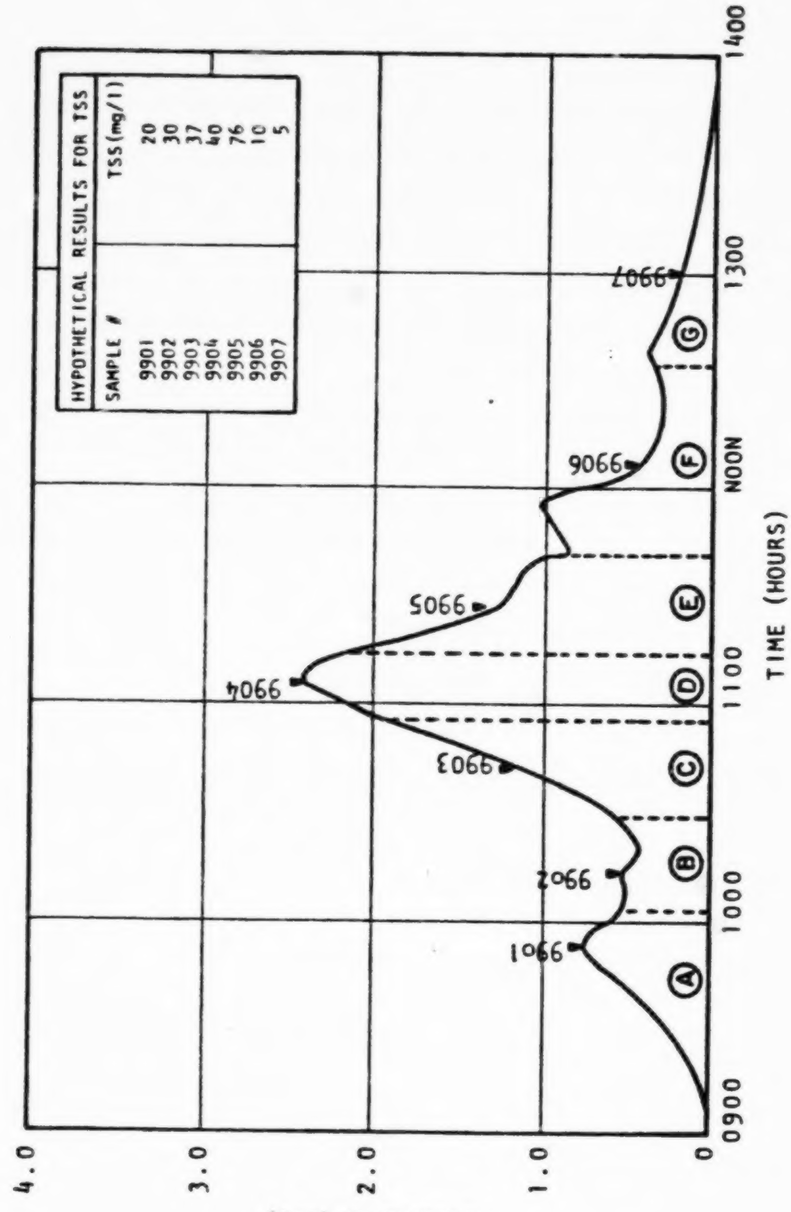
In the calculation of storm-average concentration of a particular pollutant, one begins with the storm hydrograph which is produced from the record of channel flow versus time for a particular station. Figure E-1 is a hypothetical storm hydrograph which will be used in this example. The information presented in this figure shows the time relative to discharge when each sample (numbered 9901-9907) was taken. The analytical results for each sample for the quality parameter TSS also are presented in Figure E-1. Once the sample collection times are known, the hydrograph is subdivided into sections such that each section corresponds to one sample (labeled A through G in Figure E-1). The beginning and ending times for each section are halfway between the collection times for the sample in question and the preceeding and succeeding sample times, respectively. Each of the subareas is measured using a planimeter and the measurement obtained is converted to discharge volume according to the scale of the hydrograph.

The hypothetical values for the total discharge volumes of each of the subareas of Figure E-1 are shown in Table E-1. The mass discharge of TSS associated with each subarea may now be calculated. These mass discharges are shown in Table E-2.

The storm-average concentration for TSS in this hypothetical example is (6,786,743 mg divided by 170,489 liters) or 39.8 mg/l. Similar calculations may be made for other pollutant parameters.

FIGURE E-1

HYPOTHETICAL STORM HYDROGRAPH



HYPOTHETICAL RESULTS FOR TSS

SAMPLE #	TSS (mg/l)
9901	20
9902	30
9903	37
9904	40
9905	76
9906	10
9907	5

TABLE E-1

Subarea	Discharge Volume in Cubic Feet	(liters)
A	1,000	(28,320)
B	700	(19,824)
C	1,020	(28,887)
D	1,200	(33,985)
E	1,400	(39,649)
F	600	(16,992)
G	100	(2,832)
Total	6,020	(170,489)

TABLE E-2

Subarea	TSS Concentration (mg/l)	Discharge Volume (liters)	Total Mass Discharged In mg (lbs)
A	20	28,320	566,400 (1.25)
B	30	19,824	594,720 (1.31)
C	37	28,887	1,068,819 (2.36)
D	40	33,985	1,359,400 (3.00)
E	76	39,649	3,013,324 (6.64)
F	10	16,992	169,920 (0.37)
G	5	2,832	14,160 (0.03)
Total		170,489	6,786,743 (14.96)

APPENDIX F

SUMMARY RESULTS FOR THE ANALYSIS OF METALS AND TOXIC ORGANICS FROM SAMPLES COLLECTED DURING THE AUSTIN NURP SURVEY

(Includes data for the Nationwide Priority Pollutant Survey)

The following tables summarize the data collected during the City of Austin NURP Survey for priority pollutants and metals. These data are compared to that which were obtained by all the NURP projects.

TABLE F-1

NURP PRIORITY POLLUTANT SAMPLING RESULTS

Pollutant	Range of Pollutant Concentrations in NURP* Storm Water Samples That were Above Detection Limit (µg/l)	Number of All NURP* Samples That Reported Values Above Detection Limit/ Number of Samples Analyzed for Compound	Range of Concentrations for Austin NURP Samples That Had Values Above Detection Limit (µg/l)/ Number of Austin Samples Above Detection Limit
Metals and Inorganics			
Antimony	2	1/28	–
Arsenic	3.3-37	16/28	3.3-4.6/4
Beryllium			–
Cadmium			–
Chromium	2-61	18/28	26/2
Copper	2-110	26/28	12-25/4
Cyanide	2-33	7/27	2-5/2
Lead	37.6-460	26/28	37.6-155/8**
Mercury			–
Nickel			–
Selenium	2-25	6/28	11.3-12.5/2
Silver			–
Thallium			–
Zinc	10-546	28/28	10-99/8**
Pesticides			
Acrolein		0/42*	–
Aldrin		0/42	–
Chlordane	0.01	1/42	–
DDD		0/42	–
DDE	0.35	1/42	–
DDT	0.008-0.1	2/42	–
Dieldrin	0.2	1/42	–
Endosulfan and Endosulfan Sulfate		0/42	–
Endrin and Endrin Aldehyde		0/42	–
Polycyclic Aromatic Hydrocarbons			
Acenaphthene		0/41	–
Acenaphthylene		0/41	–
Fluorene		0/41	–
Naphthalene	1-13	4/41	–
Anthracene	1-7	4/41	–
Fluoranthene	0.3-15	5/41	–
Phenanthrene	0.3-7	7/41	–
Benzo(a)anthracene	1-3	2/41	–
Benzo(b)fluoranthene	2	1/41	–
Benzo(k)fluoranthene	4	1/41	–
Chrysene	0.6-6	4/41	–
Pyrene	0.3-13	5/41	–
Benzo(ghi)perylene		0/41	–
Benzo(a)pyrene	1-2	2/41	–
Dibenzo(a,h)anthracene		0/41	–
Indeno(1,2,3-cd)pyrene		0/41	–
Halogenated Ethers			
Bis(chloromethyl)ether		0/41	–
Bis(2-chloroethyl)ether		0/41	–
Bis(2-chloroisopropyl)ether		0/41	–
2-chloroethyl vinyl ether		0/41	–
4-chlorophenyl phenyl ether		0/41	–
4-bromophenyl phenyl ether		0/41	–
Bis(2-chloroethoxy)methane		0/41	–
Phthalate Esters			
Dimethyl Phthalate		0/41	–
Diethyl Phthalate	1-5	4/41	–
Di-n-butyl Phthalate	3-11	6/41	–
Di-n-octyl Phthalate	1-3	2/41	–
Bis(2-ethylhexyl)Phthalate	1-42	16/41	18/1
N-butyl Benzyl Phthalate		0/41	–

*National Data Base as of October 5, 1981.

**4 samples plus 4 duplicates analyzed making a total of 8 samples collected.

– means no sample reported at concentration above detection limit.

TABLE F-1 (Continued)
NURP PRIORITY POLLUTANT SAMPLING RESULTS

Pollutant	Range of Pollutant Concentrations in NURP* Storm Water Samples That Were Above Detection Limit (µg/l)	Number of All NURP* Samples That Reported Values Above Detection Limit/ Number of Samples Analyzed for Compound	Range of Concentrations for Austin NURP Samples That Had Values Above Detection Limit (µg/l)/ Number of Austin Samples Above Detection Limit
Polychlorinated Biphenyls and Related Compounds			
PCB-1016		0/42	–
Aroclor 1221		0/42	–
Aroclor 1232		0/42	–
Aroclor 1242		0/42	–
Aroclor 1248		0/42	–
Aroclor 1254		0/42	–
Aroclor 1260	0.03	1/42	–
2-chloronaphthalene		0/42	–
Nitrosamines and Other N Compounds			
Dimethyl Nitrosamine		0/41	–
Diphenyl Nitrosamine		0/41	–
Di-n-propyl Nitrosamine		0/41	–
Benzidine		0/41	–
3,3-dichlorobenzidine		0/41	–
1,2-diphenylhydrazine		0/41	–
Acrylonitrile		0/41	–
Halogenated Aliphatic Hydrocarbons			
Chloromethane (Methyl Chloride)		0/40	–
Dichloromethane (Methylene Chloride)	5-1,645	19/40	178-624/4
Trichloromethane (Chloroform)	0.2-8	12/40	–
Tetrachloromethane (Carbon Tetrachloride)	1-4	4/40	–
Chloroethane (Ethyl Chloride)		0/40	–
1,1-dichloroethane (Ethylidine Chloride)	1-5	5/40	–
1,2-dichloroethane (Ethylene Chloride)	4	1/40	–
1,1,1-trichloroethane (Methyl Chloroform)	1-23	17/40	–
1,1,2-trichloroethane	1-3	5/40	–
1,1,2,2-tetrachloroethane	1/3	6/40	–
Hexachloroethane		0/40	–
Chloroethene (Vinyl Chloride)		0/40	–
1,1-dichloroethene (Vinylidine Chloride)	1-4	2/40	–
1,2-trans-dichloroethene	1-3	6/40	–
Trichloroethene	1-3	7/40	–
Tetrachloroethene	4-43	6/40	–
1,2-dichloropropane	3	1/40	–
1,3-dichloropropene	1-2	2/40	–
Hexachlorobutadiene		0/40	–
Hexachlorocyclopentadiene		0/40	–
Bromomethane (Methyl Bromide)		0/40	–
Bromodichloromethane	2	1/40	–
Dibromochloromethane	2	1/40	–
Tribromomethane (Bromoform)	1	1/40	–
Dichlorodifluoromethane		0/40	–
Trichlorofluoromethane	1-5	4/40	–
Monocyclic Aromatic Hydrocarbons			
Benzene	1-13	17/41	–
Chlorobenzene	1-3	5/41	–
1,2-dichlorobenzene		0/41	–
1,3-dichlorobenzene		0/41	–
1,4-dichlorobenzene		0/41	–
1,2,4-trichlorobenzene		0/41	–
Hexachlorobenzene		0/41	–
Ethylbenzene	1-3	8/41	–
Nitrobenzene		0/41	–
Toluene	6-9	16/41	–
2,4-dinitrotoluene		0/41	–
2,6-dinitrotoluene		0/41	–
Phenol	2-8	4/41	4-8/2
2-chlorophenol	2-22	2/41	–
2,4-dichlorophenol	10	1/41	–
2,4,6-trichlorophenol		0/41	–
Pentachlorophenol	3-115	11/41	14/1
2-nitrophenol		0/41	–
4-nitrophenol	1-19	4/41	–
2,4-dinitrophenol		0/41	–
2,4-dimethylphenol		0/41	–
p-chloro-m-cresol	1-2	2/41	–
4,6-dinitro-o-cresol		0/41	–

*National Data Base as of October 5, 1981.

**4 samples plus 4 duplicates analyzed making a total of 8 samples collected.

– means no sample reported at concentration above detection limit.

TABLE F-2

MDSD* SPECIAL METALS SAMPLING PROGRAM RESULTS**

Metal	Sample Number							
	R0851T	H0850T	H0851T	R1203T	W1201T	R1403T	H1502T	R1501T
Aluminum	60/3,050	350/1900	40/3800	<50/1200	<50/1400	<50/5450	<50/11700	<50/2550
Arsenic	<10/<10	<10/<10	<10/<10	<10/<10	<10/<10	<10/<10	<10/<10	<10/<10
Barium	90/30	180/20	150/30	30/20	130/30	80/60	110/100	60/30
Berylium	<2/<2	<2/<2	<2/<2	<2/<2	<2/<2	<2/<2	<2/<2	<2/<2
Boron	40/40	70/20	50/20	50/30	40/30	20/<10	30/30	30/20
Cadmium	<5/<5	<5/<5	<5/<5	<5/<5	<5/<5	5/40	<5/<5	<5/<5
Calcium	17800/46700	29600/30100	20900/45700	30500/33800	26600/35800	9500/82500	30700/190000	13600/39900
Chromium	<10/<10	<10/<10	<10/<10	<10/<10	<10/<10	<10/ 10	<10/ 10	<10/<10
Cobalt	<10/<10	<10/<10	<10/<10	<10/<10	<10/<10	<10/<10	<10/<10	<10/<10
Copper	<20/<20	20/30	<20/40	<20/<20	<20/<20	<20/<20	<20/80	<20/<20
Iron	40/2740	240/1600	40/2750	20/1060	40/1020	20/5140	20/8200	<20/3040
Lead	<40/130	200/210	40/220	<40/<40	<40/80	<40/260	<40/320	<40/120
Lithium	<10/<10	<10/<10	<10/<10	<10/20	<10/<10	<10/<10	<10/<10	<10/<10
Magnesium	1100/2800	2500/2700	2300/3800	1900/2000	3100/3600	500/4400	4500/11200	600/2200
Manganese	20/90	60/60	40/90	<10/20	30/140	10/170	30/300	<10/70
Mercury	<1/<1	<1/<1	<1/<1	<1/<1	<1/<1	<1/<1	<1/<1	<1/<1
Molybdinum	<10/<10	<10/<10	<10/<10	<10/<10	<10/<10	<10/<10	<10/<10	<10/<10
Nickel	<20/<20	<20/<20	<20/<20	<20/<20	<20/<20	<20/<20	<20/<20	<20/<20
Potassium	5300/6500	6200/6400	5400/6200	5000/4400	4800/4600	2600/2600	3400/3800	3000/2600
Selenium	<10/<10	<10/<10	<10/<10	<10/<10	<10/<10	<10/<10	<10/<10	<10/<10
Silver	<10/<10	<10/<10	<10/<10	<10/<10	<10/<10	<10/<10	<10/<10	<10/<10
Sodium	3000/2700	4700/3500	5500/4100	3700/2600	5600/5000	2700/1700	6800/6400	1900/1500
Strontium	40/50	40/40	40/50	40/40	140/160	10/80	60/160	20/40
Tellurium	<10/<10	<10/<10	<10/<10	<10/<10	<10/<10	<10/<10	<10/<10	<10/<10
Tin	<50/<50	<50/<50	<50/<50	<50/<50	<50/<50	<50/<50	<50/<50	<50/<50
Titanium	<10/30	<10/20	<10/40	<10/40	<10/<10	<10/90	<10/140	<10/50
Vanadium	<10/<10	<10/<10	<10/10	<10/<10	<10/<10	<10/<10	<10/20	<10/<10
Yttrium	<10/<10	<10/<10	<10/<10	<10/<10	<10/<10	<10/<10	<10/<10	<10/<10
Zinc	70/70	350/160	100/100	10/<10	10/5760	<10/40	10/80	<10/<10

NOTES: R = Rollingwood site.
H = Hart Lane (Northwest Austin) site.

*U.S. EPA Monitoring and Data Support Division.

**Results are reported as dissolved fraction (μg/l)/total metal (μg/l).

APPENDIX G

GENERAL WATER QUALITY DATA
FROM LAKE AUSTIN AND TOWN LAKE
NURP SURVEY YEAR 1981

TABLE G-1

GENERAL WATER QUALITY FROM LAKE AUSTIN
STORM EVENT 13

Sampling Date	Parameter	Depth (feet)	Station							
			ES-0-0	ES-1-A	ES-1-B	ES-1-C	ES-2-A	ES-2-B	ES-2-C	ES-3
5-1-81	Sampling Time		15:30	15:50	15:05	16:20	16:45	17:00	17:10	17:45
	Transparency, m		2.92	0.25	0.70	-	0.22	0.52	1.3	2.3
	Temperature, °C	1	20.7	23.7	25.1	25.9	24.8	23.0	23.2	21.5
		6	18.8	19.4*	17.0	16.7	21.5*	18.6	18.0	20.6
		11	15.5	-	16.2**	15.9	-	-	16.0	17.0
		16	15.3	-	-	15.3	-	-	-	15.9
		21	15.2	-	-	-	-	-	-	15.8
		26	15.2	-	-	-	-	-	-	15.8
		31	-	-	-	-	-	-	-	-
	Dissolved Oxygen, mg/l	1	8.9	6.3	6.9	6.9	6.4	7.4	7.5	6.0
		6	8.0	4.35*	6.5	6.6	6.0*	7.4	7.1	6.0
		11	7.5	-	5.6**	6.6	-	-	7.2	9.0
		16	7.4	-	-	6.45	-	-	-	8.3
		21	7.25	-	-	-	-	-	-	8.3
		26	7.25	-	-	-	-	-	-	8.3
		31	-	-	-	-	-	-	-	-
	Conductivity, μmhos/cm	1	450	510	520	525	428	483	438	460
		6	450	470*	425	418	472*	446	435	460
		11	420	-	450**	419	-	-	420	425
		16	420	-	-	419	-	-	-	422
		21	419	-	-	-	-	-	-	422
		26	419	-	-	-	-	-	-	422
		31	-	-	-	-	-	-	-	-
5-3-81	Sampling Time		17:45	16:00	18:15	16:30	19:00	19:10	19:15	19:30
	Transparency, m		2.95	0.37	0.90	1.5	0.32	1.12	2.0	2.45
	Temperature, °C	1	18.0	21.7	20.2	18.9	21.2	19.6	18.8	17.5
		6	17.9	20.5*	16.1	17.8	20.0*	17.8	17.8	16.1
		11	17.3	-	16.2**	-	-	-	17.1	15.8
		16	15.0	-	-	-	-	-	-	15.5
		21	14.6	-	-	-	-	-	-	15.3
		26	14.4	-	-	-	-	-	-	15.2
		31	-	-	-	-	-	-	-	15.1
	Dissolved Oxygen, mg/l	1	9.0	6.7	7.8	8.0	6.3	7.4	8.8	9.1
		6	8.7	6.45*	7.2	8.2	4.8*	7.6	8.7	8.8
		11	8.6	-	6.5**	-	-	-	8.4	8.65
		16	8.4	-	-	-	-	-	-	8.65
		21	8.2	-	-	-	-	-	-	8.35
		26	7.8	-	-	-	-	-	-	8.30
		31	-	-	-	-	-	-	-	8.45
	Conductivity, μmhos/cm	1	438	500	465	438	470	460	435	438
		6	435	500*	450	435	465*	458	440	430
		11	430	-	430**	-	-	-	435	425
		16	410	-	-	-	-	-	-	-
		21	-	-	-	-	-	-	-	-
		26	409	-	-	-	-	-	-	-
		31	-	-	-	-	-	-	-	-
5-4-81	Sampling Time		12:00	12:15	12:30	12:40	13:00	13:15	13:25	13:45
	Transparency, m		2.33	0.35	0.66	0.8	0.36	0.65	2.5	3.0
	Temperature, °C	1	18.0	21.0	21.0	21.7	20.9	19.8	19.6	16.9
		6	16.7	19.9*	18.0	18.3	18.3*	18.0	17.8	17.1
		11	15.0	-	17.2**	15.2	-	-	17.0	15.9
		21	14.6	-	-	-	-	-	-	15.1
		26	14.6	-	-	-	-	-	-	15.1
		31	-	-	-	-	-	-	-	15.1
	Dissolved Oxygen, mg/l	1	9.0	6.0	6.9	7.8	6.3	7.8	7.9	8.7
		6	8.7	6.0*	7.3	7.8	6.8*	8.6	8.2	8.3
		11	8.6	-	6.5**	7.8	-	-	7.9	8.5
		16	8.4	-	-	-	-	-	-	8.2
		21	8.2	-	-	-	-	-	-	8.0
		26	7.8	-	-	-	-	-	-	7.6
		31	-	-	-	-	-	-	-	7.1

TABLE G-1 (Continued)

GENERAL WATER QUALITY FROM LAKE AUSTIN
STORM EVENT 13

Sampling Date	Parameter	Depth (feet)	Station							
			ES-0-0	ES-1-A	ES-1-B	ES-1-C	ES-2-A	ES-2-B	ES-2-C	ES-3
5-4-81	Conductivity, umhos/cm	1	430	520	490	470	460	450	450	450
		6	425	450*	440	440	455*	440	440	435
		11	410	-	438**	415	-	-	435	420
		16	410	-	-	-	-	-	-	420
		21	410	-	-	-	-	-	-	420
		26	410	-	-	-	-	-	-	415
		31	-	-	-	-	-	-	-	415
5-5-81	Sampling Time		15:00	15:20	15:30	15:50	16:00	16:15	16:30	16:45
	Transparency, m		2.65	0.52	0.59	1.25	0.55	0.65	1.45	3.1
	Temperature, °C	1	19.1	21.0	21.0	20.9	20.0	20.0	19.0	19.8
		6	15.0	16.0*	16.6	15.0	16.4*	16.4	16.1	19.0
		11	14.6	-	15.1**	14.7	-	-	15.0	18.6
		16	14.4	-	-	14.7	-	-	-	18.1
		21	14.3	-	-	-	-	-	-	17.8
		26	14.3	-	-	-	-	-	-	15.2
		31	-	-	-	-	-	-	-	15.0
	Dissolved Oxygen, mg/l	1	8.8	6.5	6.7	7.4	7.1	7.9	8.7	9.8
		6	8.1	5.6*	7.0	7.3	7.6*	8.5	8.3	9.3
		11	8.0	-	6.7**	7.2	-	-	8.2	8.8
		16	7.8	-	-	6.9	-	-	-	8.5
		21	7.7	-	-	-	-	-	-	8.2
		26	7.7	-	-	-	-	-	-	8.2
		31	-	-	-	-	-	-	-	8.1
	Conductivity, umhos/cm	1	450	490	492	480	465	460	420	440
		6	410	450*	415	410	450*	425	410	440
		11	410	-	415**	410	-	-	-	440
		16	410	-	-	410	-	-	-	440
		21	410	-	-	-	-	-	-	437
		26	410	-	-	-	-	-	-	415
		31	-	-	-	-	-	-	-	410

*Depth = 4 feet.

**Depth = 9 feet.

TABLE 6-

GENERAL WATER QUALITY FROM LAKE AUSTIN
STORM EVENT 14

Reproduced from best available copy.

Sampling Date	Parameter	Depth (feet)	Station							
			ES-0-[illegible]	ES-1-A	ES-1-B	ES-1-C	ES-2-A	ES-2-B	ES-2-C	ES-3
5-16-81	Sampling Time		14:45	15:10	15:20	15:35	16:00	16:05	16:15	16:45
	Transparency, m		3.2	0.16	0.52	0.55	0.3	0.55	0.9	2.05
	Temperature, °C	1	17.2	21.8	20.5	19.0	21.6	20.7	20.2	18.4
		6	17.4	18.5*	19.2	18.2	19.5*	19.5	19.4	18.2
		11	16.2	-	18.0?	17.8	-	-	19.2	17.4
		16	16.[illegible]	-	-	-	-	-	-	16.5
		21	15.[illegible]	-	-	-	-	-	-	16.4
		26	15.6	-	-	-	-	-	-	16.0
		31	15.6	-	-	-	-	-	-	15.9
	Dissolved Oxygen, mg/l	1	6.4	7.0	7.1	8.5	6.8	6.8	7.6	7.4
		6	8.3	6.8*	6.3	6.1	6.2*	6.2	7.2	7.1
		11	8.3	-	6.5**	7.9	-	-	6.9	7.0
		16	8.3	-	-	-	-	-	-	7.1
		21	8.3	-	-	-	-	-	-	7.1
		26	8.3	-	-	-	-	-	-	7.2
		31	7.7	-	-	-	-	-	-	7.1
	Conductivity, μmhos/cm	1	420	420	460	443	442	430	440	442
		6	428	305*	440	443	402*	430	440	442
		11	425	-	440**	441	-	-	436	439
		16	425	-	-	-	-	-	-	438
		21	424	-	-	-	-	-	-	439
		26	424	-	-	-	-	-	-	439
		31	420	-	-	-	-	-	-	431
5-17-81	Sampling Time		16:00	16:25	16:35	16:50	17:20	17:30	17:45	18:05
	Transparency, m		2.95	0.2	0.45	0.5	0.35	0.38	1.3	2.0
	Temperature, °C	1	18.8	25.6	24.0	21.5	27.1	24.0	22.0	20.4
		6	18.2	25.0*	22.0	20.0	22.1*	21.0	20.3	19.6
		11	17.1	-	19.9**	19.5	-	-	19.1	18.5
		16	16.2	-	-	-	-	-	-	17.5
		21	15.8	-	-	-	-	-	-	17.1
		26	15.4	-	-	-	-	-	-	17.0
		31	15.4	-	-	-	-	-	-	16.5
	Dissolved Oxygen, mg/l	1	8.7	6.1	5.5	7.3	6.3	6.5	6.4	7.0
		6	8.1	5.5*	5.6	7.1	4.3	6.2	6.9	7.5
		11	7.9	-	4.6**	6.5	-	-	7.5	7.6
		16	7.9	-	-	-	-	-	-	7.5
		21	7.9	-	-	-	-	-	-	7.6
		26	7.8	-	-	-	-	-	-	7.6
		31	7.1	-	-	-	-	-	-	7.7
	Conductivity, μmhos/cm	1	438	490*	470	452	442	445	450	438
		6	438	494*	450	448	402*	440	440	438
		11	436	-	445**	445	-	-	435	436
		16	422	-	-	-	-	-	-	436
		21	420	-	-	-	-	-	-	436
		26	418	-	-	-	-	-	-	435
		31	420	-	-	-	-	-	-	433
5-18-81	Sampling Time		14:15	14:25	14:40	14:45	15:05	15:15	15:25	15:50
	Transparency, m		1.65	0.5	0.65	0.65	0.48	0.53	1.75	2.32
	Temperature, °C	1	23.0	29.5	27.5	25.5	29.8	26.0	23.0	24.0
		6	21.6	26.0*	20.1	20.9	21.5*	20.3	21.8	19.5
		11	17.4	-	19.0**	18.0	-	-	19.1	17.3
		16	16.3	-	-	-	-	-	-	16.7
		21	16.0	-	-	-	-	-	-	16.5
		26	16.0	-	-	-	-	-	-	16.5
		31	16.6	-	-	-	-	-	-	16.3

TABLE G-2 (Continued)

GENERAL WATER QUALITY FROM LAKE AUSTIN
STORM EVENT 14

Sampling Date	Parameter	Depth (feet)	Station							
			ES-0-0	ES-1-A	ES-1-B	ES-1-C	ES-2-A	ES-2-B	ES-2-C	ES-3
5-18-81	Dissolved Oxygen, mg/l	1	7.8	4.5	5.6	5.8	4.5	4.4	7.0	7.7
		6	7.6	4.3*	6.25	6.8	5.7*	8.2	6.6	7.7
		11	7.6	-	6.2**	7.0	-	-	7.5	7.5
		16	7.2	-	-	-	-	-	-	7.5
		21	6.9	-	-	-	-	-	-	7.5
		26	6.4	-	-	-	-	-	-	7.45
		31	5.8	-	-	-	-	-	-	7.6
	Conductivity, μmhos/cm	1	539	560	560	538	552	508	520	502
		6	520	545*	540	535	540*	535	500	495
		11	514	-	530**	515	-	-	518	488
		16	518	-	-	-	-	-	-	488
		21	522	-	-	-	-	-	-	490
		26	526	-	-	-	-	-	-	494
		31	520	-	-	-	-	-	-	490
5-20-81	Sampling Time		14:25	14:50	15:00	15:15	15:30	15:35	15:45	16:10
	Transparency, m		3.25	0.3	0.5	0.75	0.36	0.5	1.68	2.38
	Temperature, °C	1	18.1	21.0	20.2	21.4	21.5	21.0	19.8	21.0
		6	17.9	18.3*	17.3	19.0	19.0*	19.7	[illegible]	19.2
		11	17.3	-	17.0**	17.5	-	-	18.0	18.8
		16	17.0	-	-	-	-	-	-	18.4
		21	17.0	-	-	-	-	-	-	18.3
		26	16.8	-	-	-	-	-	-	18.1
		31	16.9	-	-	-	-	-	-	18.0
	Dissolved Oxygen, mg/l	1	9.3	7.3	8.3	10.0	8.7	9.2	10.0	11.2
		6	9.2	7.2*	8.4	9.85	9.0*	10.0	9.5	10.0
		11	9.3	-	8.4**	9.7	-	-	9.7	9.5
		16	9.3	-	-	-	-	-	-	9.3
		21	9.3	-	-	-	-	-	-	9.1
		26	9.25	-	-	-	-	-	-	9.1
		31	8.6	-	-	-	-	-	-	9.1
	Conductivity, umhos/cm	1	474	533	503	502	518	515	475	485
		6	474	508*	490	472	510	515	475	482
		11	474	-	484**	480	-	-	490	479
		16	476	-	-	-	-	-	-	480
		21	478	-	-	-	-	-	-	490
		26	480	-	-	-	-	-	-	485
		31	478	-	-	-	-	-	-	[illegible]

*Depth = 4 feet.

**Depth = 9 feet.

TABLE G-3

GENERAL WATER QUALITY FROM LAKE AUSTIN STORM EVENT 15

Sampling Date	Parameter	Depth (feet)	Station ES-0-0	ES-1-A	ES-1-B	ES-1-C	ES-2-A	ES-2-B	ES-2-C	ES-3
5-26-81	Sampling Time		16:25	17:00	17:10	17.30	17:50	18:00	18:15	18:45
	Transparency, m		0.3	1.12***	0.45	0.35	0.32	0.32	0.3	0.28
	Temperature, °C	1	23.2	26.4	27.0	24.5	26.6	26.6	24.0	19.2
		6	22.1	25.3**	23.5	22.5	22.3**	22.3	22.1	18.2
		11	20.0	-	21.7***	21.8	-	-	21.2	17.6
		16	17.8	-	-	-	-	-	-	17.3
		21	17.2	-	-	-	-	-	-	17.2
		26	16.8	-	-	-	-	-	-	17.2
		31	16.7	-	-	-	-	-	-	17.0
	Dissolved Oxygen, mg/l	1	7.85	7.6	7.0	6.9	7.0	7.0	7.9	7.9
		6	7.6	7.0**	7.3	6.3	6.1**	6.1	7.2	7.7
		11	7.7	-	6.2***	5.5	-	-	6.7	7.7
		16	7.6	-	-	-	-	-	-	7.7
		21	7.5	-	-	-	-	-	-	7.5
		26	7.7	-	-	-	-	-	-	7.5
		31	7.7	-	-	-	-	-	-	7.5
	Conductivity, µmhos/cm	1	438	670	550	450	580	580	415	355
		6	440	685**	670	500	590**	590	410	350
		11	410	-	595***	535	-	-	500	360
		16	425	-	-	-	-	-	-	365
		21	420	-	-	-	-	-	-	375
		26	445	-	-	-	-	-	-	380
		31	430	-	-	-	-	-	-	370
5-28-81	Sampling Time		15:00	15:25	15:35	15:50	16:15	16:25	16:35	16:50
	Transparency, m		0.78	1.05	0.74	0.6	0.65	0.61	0.52	0.7
	Temperature, °C	1	25.9	27.5	28.0	25.7	28.5	27.2	26.0	22.0
		6	25.0	25.3**	26.8	25.0	26.5**	24.3	23.1	20.2
		11	23.3	-	23.9***	23.3	-	-	22.4	18.2
		16	19.0	-	-	-	-	-	-	17.9
		21	18.0	-	-	-	-	-	-	17.5
		26	17.9	-	-	-	-	-	-	17.3
		31	17.8	-	-	-	-	-	-	17.2
	Dissolved Oxygen, mg/l	1	7.8	6.8	7.5	8.0	8.0	8.0	9.6	7.8
		6	6.1	6.3**	6.0	6.7	7.2**	6.2	7.9	7.4
		11	7.6	-	6.3***	5.8	-	-	5.6	7.0
		16	7.2	-	-	-	-	-	-	6.9
		21	7.7	-	-	-	-	-	-	6.9
		26	7.6	-	-	-	-	-	-	6.9
		31	6.8	-	-	-	-	-	-	6.9
	Conductivity, µmhos/cm	1	448	700	695	472	695	620	430	395
		6	451	690**	685	600	800**	635	408	400
		11	438	-	660***	650	-	-	435	390
		16	432	-	-	-	-	-	-	387
		21	425	-	-	-	-	-	-	382
		26	425	-	-	-	-	-	-	381
		31	440	-	-	-	-	-	-	350

*Depth = 4 feet.

**Depth = 9 feet.

***Clearing due to spring flow.

TABLE G-4

GENERAL WATER QUALITY FROM LAKE AUSTIN
STORM EVENT 23

Sampling Date	Parameter	Depth (feet)	Station ES-0-A	ES-0-B	ES-0-0	ES-1-A	ES-1-B	ES-1-C	ES-2-A	ES-2-B	ES-2-C	ES-3
6-11-81	Sampling Time		11:45	11:30	12:15	12:30	12:45	13:00	13:25	13:30	13:40	14:00
	Transparency, m		1.15	0.56	0.75	0.7[illegible]	0.5	0.58	0.5	0.5	0.45	0.45
	Temperature, °C	1	19.1	21.8	18.0	21.8	22.7	24.0	23.8	22.2	21.5	21.2
		6	17.1	21.6*	16.5	21.6*	21.7	22.0	22.5*	18.2	19.6	19.3
		11	16.4	-	16.2	-	21.2**	21.9	-	-	17.3	18.2
		16	16.1	-	16.1	-	-	-	-	-	-	17.5
		21	15.9	-	16.0	-	-	-	-	-	-	17.3
		26	15.6	-	16.0	-	-	-	-	-	-	17.2
		31	15.4	-	16.0	-	-	-	-	-	-	17.0
	Dissolved Oxygen, mg/l	1	5.8	6.7	6.2	5.6	7.2	7.9	7.0	6.8	6.8	6.8
		6	5.7	6.5*	6.1	6.2*	7.3	7.2	5.6*	5.8	5.5	6.4
		11	5.6	-	6.1	-	7.4**	7.1	-	-	5.6	6.3
		16	5.5	-	6.1	-	-	-	-	-	-	6.4
		21	5.6	-	6.1	-	-	-	-	-	-	6.3
		26	5.7	-	6.0	-	-	-	-	-	-	6.2
		31	5.65	-	5.9	-	-	-	-	-	-	6.3
	Conductivity, μmhos/cm	1	408	475	270	332	332	340	340	650	605	409
		6	408	479*	270	333*	339	352	475*	390	390	395
		11	408	-	270	-	400**	380	-	-	390	395
		16	408	-	270	-	-	-	-	-	-	395
		21	408	-	272	-	-	-	-	-	-	395
		26	410	-	385	-	-	-	-	-	-	395
		31	404	-	392	-	-	-	-	-	-	395

TABLE G-5

GENERAL WATER QUALITY FROM LAKE AUSTIN
STORM EVENT 25

Sampling Date	Parameter	Depth (feet)	Station									
			ES-0-A	ES-0-B	ES-0-0	ES-1-A	ES-1-B	ES-1-C	ES-2-A	ES-2-B	ES-2-C	ES-3
7-6-81	Sampling Time		11:45	12:20	12:45	13:05	13:15	13:45	14:15	14:25	14:40	15:50
	Transparency, m		2.61	1.08	1.9	0.48	0.50	0.52	0.35	0.46	1.22	1.5
	Temperature, °C	1	22.3	25.0	22.4	25.7	26.5	25.8	25.8	26.0	25.4	25.1
		6	21.8	23.2*	22.3	23.7*	24.7	23.8	24.4*	24.1	24.0	24.1
		11	21.8	-	22.2	-	23.3**	23.0	-	-	23.0	23.1
		16	21.8	-	22.1	-	-	-	-	-	-	22.5
		21	21.8	-	22.0	-	-	-	-	-	-	22.5
		26	21.8	-	22.0	-	-	-	-	-	-	22.4
		31	21.8	-	22.0	-	-	-	-	-	-	22.2
	Dissolved Oxygen, mg/l	1	4.2	4.0	5.3	7.4	7.0	6.0	5.5	5.9	5.4	6.3
		6	4.0	3.75*	5.0	7.7*	6.5	4.9	5.2*	3.8	5.1	5.6
		11	3.9	-	4.8	-	5.6**	4.6	-	-	4.1	4.8
		16	3.9	-	4.7	-	-	-	-	-	-	4.5
		21	3.85	-	4.6	-	-	-	-	-	-	4.4
		26	3.9	-	4.8	-	-	-	-	-	-	4.3
		31	3.8	-	4.1	-	-	-	-	-	-	4.3
	Conductivity, µmhos/cm	1	462	530	460	525	502	486	470	471	485	480
		6	463	465*	466	525*	498	472	485*	500	482	473
		11	463	-	467	-	510**	470	-	-	475	474
		16	464	-	466	-	-	-	-	-	-	475
		21	372	-	466	-	-	-	-	-	-	475
		26	370	-	467	-	-	-	-	-	-	467
		31	336	-	466	-	-	-	-	-	-	466
7-9-81	Sampling Time		10:20	10:45	10:55	13:10	13:20	13:35	14:00	14:15	14:25	14:45
	Transparency, m		2.8	0.82	2.35	0.25	0.63	0.58	0.55	0.70	1.46	2.6
	Temperature, °C	1	23.6	27.0	25.3	28.9	28.5	27.6	30.3	28.3	29.0	26.8
		6	23.1	25.0*	23.9	26.9*	25.0	25.3	29.2*	26.7	26.4	25.2
		11	23.0	-	23.4	-	24.4**	24.0	-	-	24.9	24.7
		16	23.0	-	23.2	-	-	-	-	-	-	24.0
		21	22.9	-	23.1	-	-	-	-	-	-	23.8
		26	22.9	-	23.1	-	-	-	-	-	-	23.8
		31	23.0	-	23.1	-	-	-	-	-	-	24.0
	Dissolved Oxygen, mg/l	1	5.4	5.2	5.6	7.5	7.0	7.0	6.2	7.1	6.8	6.9
		6	4.9	4.4*	5.6	7.3*	6.6	5.0	4.9*	5.2	5.3	5.6
		11	4.8	-	5.3	-	4.0**	4.6	-	-	4.2	5.3
		16	4.8	-	5.3	-	-	-	-	-	-	5.1
		21	4.7	-	5.25	-	-	-	-	-	-	4.9
		26	4.6	-	5.2	-	-	-	-	-	-	4.4
		31	4.6	-	4.7	-	-	-	-	-	-	3.9
	Conductivity, µmhos/cm	1	462	520	484	375	520	520	620	520	510	490
		6	470	460*	479	535*	482	482	620*	500	492	482
		11	473	-	478	-	483**	483	-	-	485	482
		16	473	-	474	-	-	-	-	-	-	482
		21	476	-	476	-	-	-	-	-	-	482
		26	477	-	479	-	-	-	-	-	-	482
		31	310	-	482	-	-	-	-	-	-	482

TABLE G-6

GENERAL WATER QUALITY FROM TOWN LAKE
STORM EVENT 23

Sampling Date	Parameter	Depth (feet)	Station				
			ES-4	ES-5	ES-6	ES-7	ES-8
6-11-81	Sampling Time		15:45	16:20	16:50	16:05	16:15
	Transparency, m		0.53	0.24	0.33	-	0.33
	Temperature, °C	1	18.0	20.0	22.1	22.6	22.8
		6	18.0	19.2	20.7	-	20.5
		11	18.0	19.0	20.2	-	-
		16	-	-	20.0	-	-
		21	-	-	-	-	-
		26	-	-	-	-	-
		31	-	-	-	-	-
	Dissolved Oxygen, mg/l	1	9.2	8.6	7.9	8.1	7.2
		6	8.8	8.3	7.7	-	7.1
		11	8.6	8.2	7.7	-	-
		16	-	-	7.6	-	-
		21	-	-	-	-	-
		26	-	-	-	-	-
		31	-	-	-	-	-
	Conductivity, µmhos/cm	1	390	380	404	320	425
		6	400	387	404	-	402
		11	400	390	405	-	-
		16	-	-	405	-	-
		21	-	-	-	-	-
		26	-	-	-	-	-
		31	-	-	-	-	-

TABLE G-7

GENERAL WATER QUALITY FROM TOWN LAKE
STORM EVENT 25

Sampling Date	Parameter	Depth (feet)	Station				
			ES-4	ES-5	ES-6	ES-7	ES-8
7-6-81	Sampling Time		17:50	16:45	16:30	18:10	17:00
	Transparency, m		0.62	2.02	0.98	0.66	0.9
	Temperature, °C	1	23.9	23.9	25.0	24.5	25.9
		6	23.5	23.8	24.5	24.1	25.0
		11	23.2	23.7	23.9	-	-
		16	23.1	23.5	-	-	-
		21	-	-	-	-	-
		26	-	-	-	-	-
		31	-	-	-	-	-
	Dissolved Oxygen, mg/l	1	6.4	6.8	6.1	8.7	8.0
		6	5.9	6.4	5.5	7.8	5.9
		11	5.6	6.0	5.0	-	-
		16	5.4	5.8	-	-	-
		21	-	-	-	-	-
		26	-	-	-	-	-
		31	-	-	-	-	-
	Conductivity, µmhos/cm	1	485	482	470	478	515
		6	485	490	480	480	500
		11	487	491	485	-	-
		16	487	492	-	-	-
		21	-	-	-	-	-
		26	-	-	-	-	-
		31	-	-	-	-	-
7-9-81	Sampling Time		17:00	16:00	15:45	16:40	16:20
	Transparency, m		2.2	2.05	1.37	1.0	1.0
	Temperature, °C	1	25.0	26.2	27.0	26.0	28.0
		6	24.8	25.8	25.2	25.3	26.0
		11	24.6	25.0	24.5	-	-
		16	24.5	-	-	-	-
		21	-	-	-	-	-
		26	-	-	-	-	-
		31	-	-	-	-	-
	Dissolved Oxygen, mg/l	1	6.3	6.2	6.7	8.2	6.8
		6	6.2	6.2	6.0	7.8	6.2
		11	6.2	6.2	5.3	-	-
		16	6.1	-	-	-	-
		21	-	-	-	-	-
		26	-	-	-	-	-
		31	-	-	-	-	-
	Conductivity, µhos/cm	1	495	495	495	650	670
		6	495	495	405	650	490
		11	495	495	488	-	-
		16	495	-	-	-	-
		21	-	-	-	-	-
		26	-	-	-	-	-
		31	-	-	-	-	-